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THE STATE OF THE SYSTEM (SOS) MODEL: MEASURING GROWTH LIMITATIONS USING ECOLOGICAL CONCEPTS

CHASE, ROSEN AND WALLACE, INCORPORATED

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THE STATE OF THE SYSTEM (SOS) MODEL:

Measuring Growth Limitations Using Ecological Concepts

By

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ABSTRACT

The State of the System (SOS) Model is the result of an attempt to develop a methodology that relates ecological concepts including regional carrying capacity to the social scientists' concepts of regional growth and development, and quality of life. SOS appears conceptually sound in its general relationships but it should be considered at this time as only a conceptual research tool.

The initial operational model, SOS-1, was developed to investigate details of the results predicted by the theory and to explore data requirements and needs. Therefore, the results of the model runs provided are purely illustrative and should be interpreted using extreme care. Further model development into a policy analysis technique has been postponed pending the outcome of research into improved techniques for measurement of quality of life. However, in keeping with the EPA policy of making research results available, this publication has been prepared.

The SOS Model began as an attempt to provide an example form of a constrictor model of the Decision Analysis System (DAS) to be used in conjunction with the General Environmental Model (GEM). A discussion of the DAS is given in Dr. House's paper, "Decision Analysis for Environmental Management." During the design of the constrictor model, SOS took on a life of its own as a stand-alone model. It is intended that the later developments of SOS should complete this development as a constrictor model within DAS as well as continue its refinement as a stand-alone analysis tool. The model, as given in the SOS-1 form, is flexible and new data and algorithms can be substituted with relative ease. In order to maintain this ease in later, more complex versions, segmentation of its procedures into smaller modules would be useful. Such a form will increase the utility of SOS as an educational and research tool.

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ACKNOWLEDGMENTS

The development of the State of the System Model to its present form of an operational model for testing alternative research concepts is the product of a three stage research effort; this effort has included work by many other researchers in addition to the principal authors. As such, the research represents the development of an operations research product in the classical way of combining the products and talents of a number of professionals into an integrated final product.

The initial concepts were developed by Dr. House and were amplified by Sam Ratick, Bob Livingston, John Gerba and Tom Parry of the Environmental Studies Division. Their work, later expanded by the authors, is represented in Sections 2-6 and Appendix 1 of this report.

The design, programming and documentation of the example model, SOS-1, was produced by a project team of Chase, Rosen & Wallace (CRW), and included Ernest Heilberg, Roma Malkani and Penny Colley as well as Mr. Williams.

The model refinement, data collection and model test were performed by CRW, assisted by members of Dr. House's division plus Sted Noble of International Research and Technology. CRW's effort is documented primarily in Sections 7-9 and the other appendixes.

The total effort to bring the original concept to the status documented in this report was an eight month period. This development in such a short period reflects well on the imaginative reasearch and teamwork of all staff members.

SECTION I

CONCLUSIONS

Many analyses of regional resource limitations and environmental damage being caused by population and industrial growth predict that major, catastrophic problems will occur. The question arises; is the perceived level of catastrophy a function of the situation or a function of the analysis? It appears that a regional model that includes not only an element that describes a region but also a systemic element that adjusts consumption processes to reduce use of limiting factors might help answer this question.

The forms and the limits of system adjustment used in the proposed model require representation of both the economic levels and the physical levels of resources and limiting factors that are consumed or modified in the region. These needs suggested that the concepts applied by ecologists in the analyses of natural ecosystems might be the appropriate context for representing the physical aspects of our human ecosystems while the economic constraints affecting levels of consumption of the physical limits are best represented by the traditional laws of supply/demand pricing structures. These laws should include dynamic unit cost structures so that resources could not be exhausted no matter what level of funds existed in the area. Also, the level of unit costs should control feasible expansion of economically available reserves and determine when improved utilization of similar resources can be substituted for critical limiting factors.

A general model formulation, the State of the System Model, was developed using concepts that represent the region of interest as an ecosystem dominated by human demands. Measurement of the ability of the human ecosystem to maintain growth of man, the dominant species, and growth of his "nutrient-demands" under a set of limiting factors is the primary interest in the model design. The basic concepts of this general formulation appear to reduce some of the limitations of previous regional models.

The general design was followed by development of a simple operational model (SOS-1) to test the basic proposed adjustment mechanisms and concepts. To text the model credibility and sensitivity, a data base generally representative of values and trends of the United States in 1970 was used. While much of the data are only rough approximates and the aggragation of model components is high, a test analysis was performed that appears quite credible. Specific findings that were developed include:

- If specific resource utilization trends are continued with no adjustment of levels of use of critical resources, depletion of some natural ores would depress some production areas by 1977. (Run 13, Appendix 8) *

- Assuming that production adjustments are made using available technological capabilities, the present population, and the production growth rates, some minor problems will occur prior to 1990 but these fluctuations are only temporary. However, by 1995 the present production patterns would cause long-term depletion of some nonrenewable natural ores that in turn would cause shortages in several major production areas. (It should be kept in mind that a limited set of adjustment procedures were represented in the test data base; hence, the actual system has many more adjustment options.) (Run 1, Section IX)

- Since the 1970 trends caused major resource depletion and a ragged production pattern, several procedures to limit these effects were tested including reduction of annual operating funds and limiting population expansion. The best single adjustment factor in the modified data base is limiting production operating funds. (Run 2-7, Section IX)

- Under the conditions of the test data base, the smoothest growth patterns were achieved by setting annual investment growth of all components to 2 percent. Then resource adjustments were sufficient to suggest long-term replenishment and adjustment can be achieved while the population and per capita demand satisfaction maintain steady, increasing patterns. Below 2 percent, the trend was smooth but has diminishing support of population demands. At 4 percent or higher investment, ragged economic trends and higher resource depletions occur suggesting a likelihood of severe short term effects. (Section IX)

- Reduction of population growth from current (1970) birthrates to ZPG, even when fund growth rates were set at 2 percent produced a less satisfactory level of demand satisfaction. Available work units in the labor force became a significant limiting factor at ZPG. (Runs 10-12, Appendix 7)

---

*Later data suggest less critical situation (see page 269).

- Adjustments that include control or moderation of per capita demands reduce system stress, increase system resistance to failure and allow the system to produce solutions that are marginally better balanced toward the initial (1970) value system. (Runs 8-9, Appendix 6)

Thus the set of runs of SOS-1 performed using the initial abbreviated data base support an analysis that concludes:

The severe resource limitations that occur statically within 7 years are due to lack of adjustments. In fact, at present funds investment trends and population growth rates, the regional adjustments will allow a viable society for 25 years. However, during that time severe production dislocations and major resource shortages will cause a quality of life (QOL) pattern that is ragged. Reduction of investment rates and reallocation of funds among the production components can produce an regional expansion that will stimulate resource increases and will support a population at close to the unrestricted growth rate with a stable QOL. Reduction of operating funds growth to zero and/or population birth rates to ZPG are overreactions that produce less stable and productive systems.

Based on these limited, test-bound data, a best growth solution produced by the model for the region appears to be a birth rate about one and one-half times the gross death rate, a funds growth rate about 2% per year allocated to emphasize areas of least-destructive resource usage, plus maintenance of per capita expectations at close to the present levels in goods while allowing moderately increasing expectations for services.

The SOS Model concept appears useful and in its present form and an improved data base provides a simple, aggregate analysis capability. It appears that future development should take two routes:

- Continues development of a simple model form that uses a small, aggregate data base that is easily modified for use in quick-reaction general analyses.
- Expansion of the level of model detail and inclusion of specialized algorithms to allow more detailed study of specific processes and limiting factors within a holistic regional analysis context.

For the aggregate model, the present algorithms with minor modification appear appropriate after some improvement in the interpolation calculations. Primary emphasis should be in expansion of available substitutions, refinement of data bases, research into improved population demand measures, plus modification of the program structure to make it an easy tool to be applied by users.

The development of a more detailed State of the System Model requires a several-phase analysis/development plan. This plan should include a large disaggregation of data base elements as well as development of improved micro-representations of production processes, product flow between processes, and economic and political constraints. Due to the expected long-term development time for achieving a fully-developed general model, it is appropriate to perform first an analysis of the typical problems to which SOS modelling and analysis can be applied, and then structure a development/applications plan that will allow early, partial analysis payoff while research and development continues on an evolutionary schedule.

SECTION II

INTRODUCTION

PROBLEM BACKGROUND

The "generation gap," so evident in the sixties as the youth culture gained recognition, grew to such proportions that many elders shifted from tolerance to counter-rebellion. Without arguing the pervasiveness of the youth subculture, it is useful to recognize the underpinnings of the phenomena. The counter-culture was apparently the inverse of an existing culture and, at least in its early days, rejected all of the contemporary American ethos as illegitimate and useless. This extreme posture attracted sufficient public attention so that the issues were examined across the resulting polarity. Those portions of both extreme positions which appear most useful to society are slowly being melded into a new ethos.

Similar turnabouts can be found throughout sociological literature as research, action and reaction flow from one period to the next. One example is of particular interest for this paper. For years, both public and private planning has practiced its art assuming a fruitful earth. Problems were usually couched in terms of improving societal efficiency. For example, a comprehensive or master plan was normally prepared for a community to answer questions of its ultimate size and the most efficient way to spatially distribute the people and their activities. A few of the better plans have included social amenities or other qualitative goals. Few of the plans questioned the probability of achieving the goals that were established in the plans.

On the other hand, an increasing reaction against the "growth at any cost" school has come from a number of environmentalists. Some have even seriously suggested that all growth be stopped immediately in some regions. These conflicting perspectives, like those in the youth vs. establishment conflict, cannot result in viable goal statements without compromise of the polar positions. The purpose of this paper is to describe a model that will analyze the possible ranges of social and economic growth under conditions of limited available resources and minimal environmental damage. Thus our model parallels the procedure of compromise and melding cited earlier.

With the objective above in mind, let us reflect on the goals of local and regional communities to provide the better things of life for their citizens. In the past few decades, the unfettered development of our cities and suburbs, responding primarily to economic stimuli, has not achieved its purpose of providing maximum benefit to the majority of the society. Recognition of this failure became institutionalized with the widespread appearance of the planning profession. The nation soon saw the appearance of the "master" plan and more recently, the comprehensive plan. The latter plan was envisioned as the guide of how a community could (and should) structure its total growth picture including population, labor, urban form, transportation, tax laws, and easement and land rights.

At present, many planning efforts to control the development of an urban area are based on the thesis that growth and the preservation of the environment must be symbiotic, not conflicting, goals. This perspective on environmental quality challenges the unlimited growth assumptions of the early planners, invalidating a great number of the early plans. This occurs because these early plans were seldom subjected to any credibility test other than to see if the current political community and the citizenry wanted to aim at the goal-plan. The plans were seldom subjected to the test of reality in terms of the communities actually being able to achieve the prescribed goals within the expected time frames. This lack of testing is not surprising, since the planners and their communities both subscribed to the beliefs that this was the nation of inexhaustible resources and that technological ingenuity that could solve any problem. Today, we are beginning to question the possibility of unlimited growth. Thus the comprehensive plans of localities need to be tested for realism under situations of limited resources and established required environmental qualities.

THE REAL WORLD DICTATES

Adjusted for the mandates of the pragmatic world, the wedding of the diverse goals - growth and environmental preservation - will only be accomplished through intensive environmental management. Unfortunately, having named the required cure, we are not further along in development of a procedure to implement the cure.

First step toward environment management are along the worn path of attempting to reduce all of the alternatives to a least common denominator so that they can be objectively traded off against each other. Some cost-benefit analyses of this variety have been attempted. On the assumption that no benefit can be gained without a corresponding cost, such a methodology attempts to corrolate the costs and benefits. Unfortunately, the environment is nothing if it is not comprehensive; it is related to everyone and every action and they are related to it. The environmental relationships are difficult to define in general and almost impossible to define in detail. The delineation of environmental-societal relationships is often subjective, and the perception of the linkages are correspondingly vague. Hence, this approach has met with limited success.

This paper will deal with a second approach. The ecologist's rhetoric speaks of a "holistic" representation of the man-environment relationships. This analysis approach attempts to reduce the set of possible components to a dominant group which can be handled conceptually from the vantage point of the whole system. According to its proponents, this perspective best assures that all of the various subsectors of the system will be taken into account and that the chance for occurrence of totally unexpected events will be mitigated. Additionally, the holistic school argues that the overview has to be continued over a period of time, since present-day actions not only affect all portions of the system, but continue to do so for long periods of time with decision effects often occurring after significant delay.

In short, a planning system set up to develop holistic guidance would display to the decision maker the widest set of options possible for his decisions. Its dangers include that the system would also provide him the greatest potential for confusion due to information overload.

Operationally, such holistic planning systems must require a change from the planning assumptions of the past. The extrapolation or trend continuance paradigm must be altered. Planning cannot assume that the future is merely more of the past and that the public role is to provide those goods and services necessary to assure a foundation for the laissez faire growth of the private sector. Peterson(1)* suggests that there is a rapidly developing counter view that:

- Today's problems are a result of successes as they were defined in yesterday's terms,
- An extension of the past is not generally the right prescription for the future,
- The primary planning goals for this nation should be altered to high quality livability as the major long-term objective with economic development shaped to compliment this overriding determinant,
- Science and technology, if oriented toward harmony with nature, can, within limits, assist in reaching the highest attainable quality goals, and

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*Parenthetic numbers refer to references listed at the end of the body of this paper.

- Through social and political action it is possible to design, modify or block growth and development trends based on their compatibility with long-range planning goals that are supported by a popular consensus.

MODELS OF REALITY

There are several ways of helping the environmental manager as he begins to make decisions in this new milieu. One of these methods is application of modelling. The model described in this report is in an early stage of development; it needs significantly more design before it can be used for policy use. This model likely never would have had an audience in the public sector if it had not been for the current interest in many U.S. regions in preserving and restoring an aesthetically pleasing and healthy environment coupled with the growing uneasiness about the acceptability of unlimited growth assumptions.

A brief statement should be made as to the utility of mathematical computer-based models. All decisions are based on models of one sort or another. Almost no problem is simple enough to be defined in absolute terms; for decision purposes, it must be abstracted to the level of its most dominant components. A computer model merely makes this process explicit. Further, these explicit statements of assumptions within the model, coupled with the inherent nature of a computer, allows us to try to capture a far larger set of variables than is usually attempted in day-to-day intuitive decision-making. Of course, the validity and utility of any model is a function of the accuracy with which the model designers reduced the problem area to pertinent model variables and relationships; the same characteristic is true of all problem-solving techniques.

The eventual users of the model described here will be well advised to take these caveats into consideration. The developers of this model can not state with absolute certainty the confidence factor to be attached to the output of such models. However, like most policy information, the direction of the predicted effect and the order of magnitude of the change appear correct. Thus, the State of the System Model should provide new insight into the real-world situations.

AN INTRODUCTION

The remainder of this paper provides greater detail on the current concepts and status of the State of the System (SOS) Model. The discussion is presented in seven sections, as follows:

- Environmental Carrying Capacity - The next section presents some major concepts on which the model is based. That discussion focuses on environmental carrying capacity, i.e., the limiting factors of the ecosystem, and the interaction of man with the carrying capacity.

- Resources of the Human Ecosystem - This section supplements the first by providing a discourse on problems related to man's utilization of resources. These concepts form the backbone of the system adjustment procedures of SOS.

- Model Overview - The next section is a nonmathematical discussion of the major features of the model. It presents the model in diagramatic form and includes discussion of assumptions, components, and envisioned application.

- Model Formulation - Presented here are the major mathematical relationships involved in the model, indicating the types of data required.

- Example Model - This section describes the initial operational model SOS-1 that has been developed to demonstrate the concepts presented in this paper. This model is operating; the program is fully documented in appendixes of this report.

- Example Data - All data used as the normal data base for SOS-1 is presented as scaled for model use. This data base for initial conditions is representative of 1970 U.S. data.

- Model Test - The last section details the input data used and the results obtained in a test of the example model. Summary and detailed model outputs are presented and an initial analysis of some aspects of model sensitivity are provided.

SECTION III

ENVIRONMENTAL CARRYING CAPACITY

THE ECOSYSTEM

In developing the concept of the "carrying capacity" of the environment,* it is necessary to begin with the ultimate of all physical systems, the ecosystem.

All of our actions affect our physical environment. To solve environmental and resource allocation problems in a total context, planners must understand that society depends on ecosystems for survival. Further, understanding what ecosystems are and how they work provides insights into ways to understand and reduce environmental and resource problems.

In Concepts of Ecology, Kormondy defines an ecosystem as "the abiotic physico-chemical environment and the biotic assemblage of plants, animals and microbes."(2) Thus, an ecosystem is the conglomeration of the living and non-living entities of a particular locale. Ecosystems are not one size; the entire Earth is an ecosystem, and alternatively, its smallest puddle is an ecosystem. Both examples fit the definition of ecosystem with corresponding components, processes and properties.

ECOSYSTEM COMPONENTS

Separation of the biotic (living) and abiotic (non-living) parts of an ecosystem is difficult. Elements are in a constant state of flux between various living and non-living states; very few substances are confined to a simple state. Perhaps the easiest way to examine ecosystems is through their component parts. Odum, in Ecosystem Structure and Function lists six components that comprise an ecosystem:

- Inorganic substances (carbon, nitrogen, carbon dioxide, water, etc.) - These substances are included in material cycles within the ecosystem.
- Organic compounds (proteins, carbohydrates, etc.) - These compounds link biotic and abiotic substances.
- Climate regime (temperature, rainfall, sunshine level, etc.) - The climate will have a profound effect on which organisms can prosper in a given ecosystem.

---

*Environmental carrying capacity -- the level of population and activity that the environment can maintain, given set technologies and behavioral practices.

- Autotrophic organisms (producers) - These components are largely green plants which are able to manufacture food from simple substances. Autotrophic means "self-feeding."

- Heterotrophic organisms (comsumers) - These are largely animals which ingest other organisms. Heterotrophic means "other-feeding." There are three types of heterotrophic organisms:

    - herbivore (primary consumer or "plant eaters") - herbivores get their energy directly from plants;

    - carnivore (secondary consumer or "meat eaters") - carnivores get their energy from green plants by consuming herbivores

    - tertiary consumers - carnivores that feed on other carnivores

- Decomposers - Organisms like bacteria and fungi break down complex substances into more elemental substances.(3)

A stylized relationship between the components of the ecosystem is privided in figure 1.

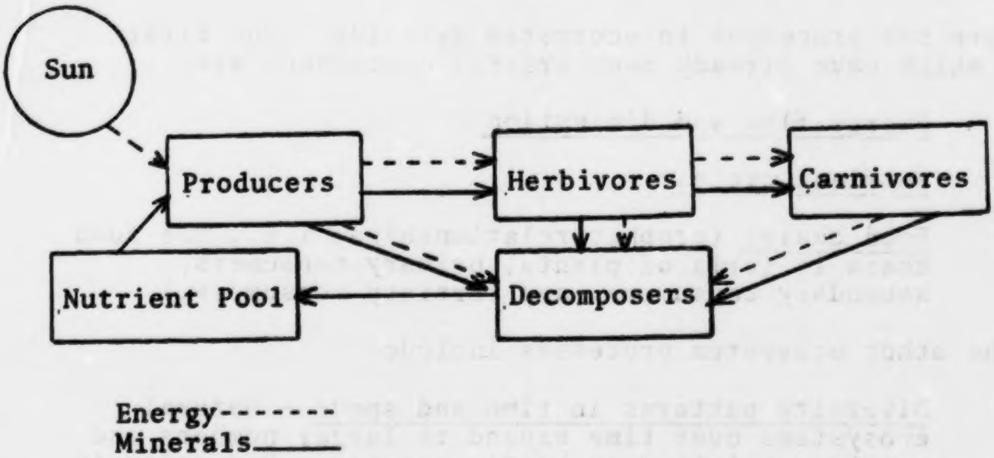

Figure 1. Ecosystem Energy and Nutrient Conversions

The major processes of the ecosystem, as pictured, work in this well known way: the producers (green plants) get energy from the sun. In the process of photosynthesis they use materials from the nutrient pool (in the media of air, water and soil). The herbivores consume the green plants absorbing both energy and minerals, and subsequently, the carnivores, by consuming herbivores, get these products. When the producers, herbivores and carnivores die, the decomposers break the organisms down into materials which are returned to the nutrient pool. Thus, the process is cyclical, with exogenous periodic input of energy from the sun. When other aspects of ecosystems are discussed in this paper, the details and amplifications should be viewed as to how they would fit in the simple ecosystem diagram of Figure 1. This central ecosystem and its workings are imbedded within all of the adaptations of localized phenomena. To reword the process and its residues:

"There is a progressive diminution of energy in this trophic or feeding chain, but the nutrient component is not diminished; in fact, some [nutrients] may even become concentrated in certain steps of the chain ... nutrients are not lost in the manner of energy, for when nutrient-containing protoplasm is eventually subjected to decomposer activity they [the nutrients] are potentially available for re-use, for recycling."(4) Energy diminution and nutrient cycling are at the heart of ecosystem dynamics.

ECOSYSTEM PROCESSES

There are six processes in ecosystem dynamics: the first three, which have already been briefly discussed, are:

- Energy flow and diminution
- Nutrient cycles
- Food chains (trophic relationships, i.e., the food chain in terms of plants, primary consumers, secondary consumers, and tertiary consumers.)

The other ecosystem processes include:

- Diversity patterns in time and space - Natural ecosystems over time expand to larger numbers and greater varieties in biotic species. Diversity is directly related to the maturity and stability of ecosystems.

- **Development and evolution** - Ecosystems develop from initial rapid and successive growth stages to maturity - a "climax" state. This state is usually an oscillating, but stable, system. The early successional growth stage is characterized by a high production/respiration ratios, high yields, short food chains, low diversity and small size of organisms, open nutrient cycles and lack of stability. In contrast, stages of ecosystem maturity have a high biomass/respiration ratios, complex food chains, low net production, high diversity and high stability.
- **Cybernetic control** - Control in ecosystems is by sets of feedback mechanisms that regulate growth and mix within the components of the ecosystem.(5)

ECOSYSTEM PROPERTIES

There are four essential properties of ecosystems. These properties form the framework for the actions and interactions of the components and processes of the ecosystem. Ecosystems all share:

- **Historical continuity** - The ecosystem responds to past and present events (past events through the succession of previous stages).
- **Spatial accessability** - The ecosystem responds to specific events at several different points in space. Each component is not an independent unit in itself, it is related to and affected by other components. The level of the interaction is usually associated with the proximity of the components.
- **Systems control** - The ecosystem encompasses many different component activities governed by complex feedbacks and interactions.
- **Structural inertia** - ecosystems and subelements exhibit characteristics that are defined in terms of time lags, and minimum and maximum constraint levels. Thus change and symptoms of interactions do not appear instantaneously, nor are all changes smooth and evolutionary.(6)

The **systems** and **structural** properties require more discussion since two important characteristics of ecosystems, **stability** and **resilience**, are defined within their context.

Ecological systems are not in a state of delicate balance. They have demonstrated in many instances the capability to either "bounce-back" or to "adjust" after severe shock. Nor did man invent severe shocks to ecosystems; long before man emerged as a dominant factor of regional ecosystems, systems were subjected to trauma by climatic changes and other geological processes. The surviving ecosystem forms were those that were able to adapt or to absorb the effects of the trauma. The capability of a system to absorb trauma and recover is its characteristic of stability. The capability of a system to successfully change to a modified form characterizes its resilience. Evolving successional ecosystems are characterized by a high level of resilience, while mature systems usually include high stability.

While major regional ecosystems have demonstrated considerable resilience, we know that their levels of resilience are not infinite. Examples of forests turning into deserts, or lakes into the aquatic analogs of deserts, exist. Thus, a key feature of ecosystems is that, as resilience is lowered by an incremental series of adaptations or a massive shock, the level of ecosystem resilience may be exceeded and the system may show unexpected and dramatic levels of change.(7) This comes about when the structural thresholds - or the demands on the system - cannot be met.

Thus, an ecosystem may react in several levels to pertubations:

- A minor change may be noted that is within the thresholds of the structure; the system will eventually return to its previous equilibrium point and meet all processing demands.
- A major change may be noted that exceeds some of the structural thresholds; the system may eventually successfully adapt by finding a new equilibrium point near the original one with a new set of structural thresholds for this equilibrium point.
- A major change may cause damage to a degree that successful adaptation does not occur; the system reaches equilibrium at much lower levels of component support and will include a vastly different set of structural thresholds.

Succession, change, stability and resiliency in ecosystems are interrelated. "When a large area is stripped of vegetation, a historical process begins that leads to the evolution of a stable ecosystem through a series of successional stages. Early in this succession, pioneer species occupy the space and the diversity and complexity of the species and the systems [processes] are low. The species that can operate under these circumstances are highly resistant to extreme conditions ... and are highly productive. Competition is low and a large proportion of the incident solar energy is converted to the production of biomass (the standing stock of organic material). As biomass accumulates, the conditions of the area begin to improve and permit the appearance of species of plants and animals that otherwise could not survive. The result is a gradual increase in the variety of species and in the complexity of their interactions, and this increase in complexity is accompanied by an increase in the resilience of the system and a decrease in biomass productivity. Under stable conditions this successional history can continue until a stable (climax) ecosystem evolves."(8)

Because an ecosystem is constantly changing, so will its equilibrium point. Even when a climax ecosystem has been reached, it is still dynamic, still changing. Ecosystems that have survived through time are the ones that have been able to keep their demand thresholds broad enough to absorb unanticipated shocks and the accumulated consequences of change over time.

ECOLOGICAL CARRYING CAPACITY

Since this approach is concerned with defining and studying environmental carrying capacity, it is useful to begin with a description of ecological carrying capacity in the classical wildlife biologist's terms.

"Carrying capacity is the ability of an ecosystem to support a given number of consumers and remain healthy and productive." In examining ecological carrying capacity, we will consider the ecological laws proposed by Danserau as the framework in which the species will act:

- Law of Inoptimum - No species encounters in any given habitat the optimum condition for all its functions.
- Law of Aphasy - Organic evaluation is slower than environmental change on the average and hence, migration occurs.
- Law of Tolerance - A species is confined, ecologically and geographically, by the extremes of environmental adversities that it can withstand.
- Law of Persistence - Many species, especially dominants of a community, are capable of surviving and maintaining their spatial position after their habitat and even the climate itself has ceased to favor full vitality.

- Law of Factorial Control - Although living beings react to all factors of the environment, there frequently occurs a factor which has controlling power through its excess or deficiency (limiting factor).

- Law of Irreversibility - Some components do not renew themselves, because they were the result of a process (physical or biological) which has ceased to function in a particular habitat or landscape at the present time.(9)

Population Growth of Species

Population dynamics are an integral part of carrying capacity. The growth of a species population will generally have the form shown below:

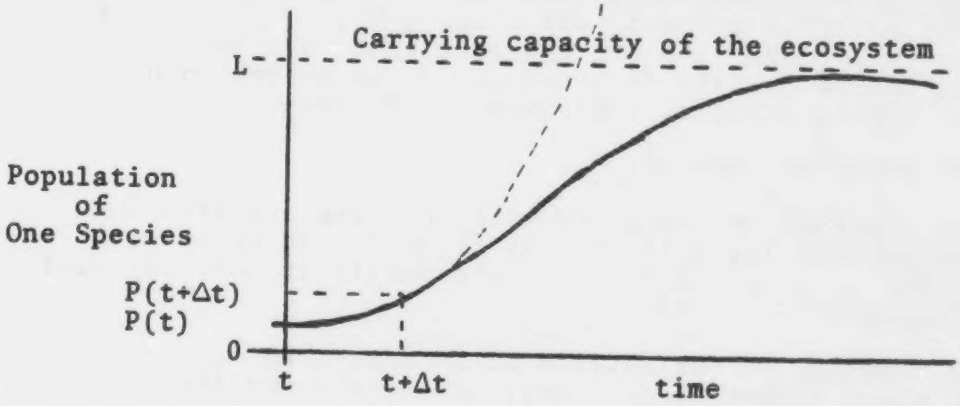

Figure 2. Population Growth in Finite Systems

Under most circumstances a new population grows "exponentially," i.e., according to the equation:

$$P(t+\Delta t) = P(t)\exp(r\Delta t)$$

where $P(t)$ is the population of the species at time t
r is the net growth rate (births minus deaths)
Δt is a time increment.

This relationship is reflected in the graph by the lower portion of the solid curve, and its dashed extention. Such an increasing trend cannot be expected to continue indefinitely in a limited environment or area.

"As the limits of the environment are approached, it can be expected that mortality will increase. Some animals perhaps will not obtain enough food; others exposed in their search for food, will fall prey to enemies; others, weakened by food deficiencies, will die from disease. As the breeding females fall off in condition, through lack of food or disease, a decrease in natality will follow. The closer the capacity of the environment is approached the greater will become the influence of decimating factors. Consequently, the curve of population growth will be bent downward again; eventually it will level off at a point where birth and death rates are in balance. This point will be the capacity of the habitat to support animals."(10)

The reduction in growth rate, as the carrying capacity of the ecosystem (line L in the graph) is approached, can be approximated by defining a variable net growth rate using:

$$r = r'[L-P(t)]/L$$

where r' is the unconstrained growth rate
L is the carrying capacity.

When $P(t)$ is small relative to L, this relationship results net growth rate, r, that is approximately equal to r'. On the other hand, as $P(t)$ approaches L, the net growth rate becomes smaller and is ultimately zero if $P(t) = L$.

Each species population in an ecosystem will occupy an "ecological niche" - a combination of species function and habitat. "Species occupying closely related niches have evolved in such a way that conflict between them is ... kept down to a level where they can all survive."(11)

A somewhat more complex treatment of population growth should, however, include consideration of the competition and demands among the species who share a locale and its resources. As the carrying capacity of the locale is approached by any one species the growth rates of all local species are affected. This can be reflected by further modifying the net growth rate to:

$$r(i) = r'(i)*\left[L(i)-P(i,t)\right. /L(i)-\sum_{j\neq i} A(i,j)*\left[L(j)-P(j,t)\right] /L(j)$$

where i indexes all of the particular species in competition
$A(i,j)$ is a coefficient of interaction between competing species i and j
and the summation is performed over all other species in the locale.

Communities of Species

Ecosystem carrying capacity depends greatly on how the community (the collection of all indigenous species) evolves and changes. As the ecosystem changes over time, so will its carrying capacity. The intricacies and interrelationships of species within a community can outlined in terms of the principles of community evolution:

- All species evolve in communities with interaction with other species; (and thus the carrying capacity of the ecosystem to maintain one species of a community may depend on the population levels of other species).
- The evolution of a community must entail "parallel" or coadaptive evolution of the community's species since the community is an assemblage of interacting and coevolving species.
- Hence, communities similar in resources and species change and may diverge in structure and function from a central community through evolutionary time.
- Through this evolution there will appear adaption to localized environment for the community as well as for species. From this adaptation to localized variety results a mosiac of communities adapted to the mosaic of the world's environments.(12)

Thus, the carrying capacity of the ecosystem is variable and responds to changes at both the community and species levels. When addressing the carrying capacity to support one particular species, one has to look at the entire ecosystem and the relationship of the population of the particular species to other species and communities of its locale.

Limiting Factors

The ability to identify the limiting factors of an ecosystem is important in determining its carrying capacity. The limiting factor is the requirement that is present to the minimum extent porportion to the needs of a collection of ecosystem components.(13) Factors in an ecosystem that can be limiting include:

- food
- climate
- ecosystem space (e.g., land)

- cover and protection
- extent of the niche of species
- amount and distribution of water
- species decimating factors - predation, disease, etc.
- rate of species change or succession.(14)

An important factor to note in determining a carrying capacity for a population within an ecosystem is that the species is part of, and subject to, changes in the ecosystem. The contained species react to changes in the ecosystem and make adjustments in order to survive; they do not change the ecosystem to meet their needs. Ultimately, this is the control property with which we must deal when we look at "environmental carrying capacity" for man within a system.

EFFECTS OF MAN ON THE ECOSYSTEMS

The evolution of man has introduced into many ecosystems a species that clearly and increasingly dominates other species. The characteristics of man that promote him as a dominant species are:

- Culture* - man can develop culture and apply it; the application of culture by man plays a major role in evolving and reshaping the relation of man and his physical world (ecosystems).
- Mobility - through mobility, man can apply culture for specialized functions in best production areas. Transport of products can modify local systems that do not include the production function. Hence, a local area may not be a closed ecosystem but may supply and be affected by factors and events not developed locally but in distant areas of Earth.
- Social - man has overlaid the natural, symbiotic relations of organisms with social constraints and judgments, causing local patterns of adjustment to depend on both social and ecological processes.

Thus the inclusion of man in regional ecosystems provides a dominant species that:

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*Skills, ideas, arts, etc. of a people at a time.

- Through culture, modifies natural levels and cycles of energy and mineral utilization and return to resource pools.
- Through mobility, augments or withdraws from the resource pools of a local ecosystem.
- Through social regulation, utilizes resource pools and changes populations of other species in patterns not compatible with natural evolutionary and environmental processes.

But man can only modify cycles and pools of non-closed ecosystems; he is still subject to the extent of the ecosystem carrying capacities and the mobility of resources that act as limiting factors. If his modifications and demands are sufficient to drive the ecosystem past a limiting factor threshold, he will cause a reduction in the carrying capacity by exceeding the threshold of an ecosystem limiting factor.

Thus the species man, like other species, is subject to the ecosystem relations of:

- Physical - man's body is subject to the natural laws that apply to all abiotic and biotic substances.
- Natural - man is affected by ecosystem factors such as climate, food, disease and media quality.

He, like all organisms, consumes energy and is part of the food chain, and through discharge of wastes and death, provides decomposable matter for renewing the nutrient pool. However, as a species employing culture and social judgment, man interacts with his environment in a manner of greater complexity than that of a physical mass and an organism.(15)

It is in the context of the ecosystem and its constraints on man's needs and wants that the concept of environmental carrying capacity for man will be defined. However, man's social and technological abilities to modify ecosystem constraints need to be specified within this context. They are both powerful shapers of man's environment - both in degrading it and in finding nondestructive ecosystem modifications.

MAN ACTS, THE ECOSYSTEM REACTS

Through the medium of culture man has proceeded through a series of technological levels to manipulate his environment over the short run. This mechanism has allowed him to expand his ecosystem niche, to regulate the quantities and locations of all other species in his communities, to modify rate of production of natural products, and to convert system components to specialized products that are not normally part of natural ecosystems. However, application of culture has also fostered new growth rates in species population and consumption of non-food specialized functions. The specialized product growth levels have caused consumption rates of limiting factors in major regional ecosystems that are far beyond the levels that are being naturally recycled back into the resource pools. Even the use of mobility to augment these localized resource needs is insufficient since world supplies of some limiting factors are being exhausted.

Thus, it appears useful to trace rapidly the evolution of man and his application of culture, and by this means identify patterns of specialized man-environmental relationships that need to be included in analyses that expect to predict the likely outcome of man's impacts on regional ecosystems. Since the aim here is to model interaction of human population growth and its demands on environmental carrying capacity, the levels of impact and primary changes of these demands will be noted.

The Niches of Man

Man, by application of accumulated culture has proceeded through four major niches or stages within his ecosystems and appears now to be entering a fifth niche. The four stages have been within ecosystems that, in most regions, would be defined as mature, climax ecosystems possessing great stability. Yet, to pass from each of the first three stages; man, through application of technology, instituted a new set of limiting factor thresholds on the ecosystems. Thus man superimposed within the natural ecosystem constraints, dramatic expansion of his niche, his population size and his quality of life. Expansion of any of these caused an increase in demands placed upon the resources of the ecosystem in which he had influence. The increased demands, even in the earliest stages, caused damage in the locale of his habitation. Fortunately, in early stages the ecological accessibility and the population density of man was sufficiently low as to provide spatial limitation of the damage. The niche provided man in the fourth stage included parallel and rapid worldwide expansion of population, quality demands, and ecological accessibility. These forced the present situation in which man cannot simply migrate locally or apply technology to effectively modify resource utilization. He must also recognize the ecosystem limitations for large regions and recognize that he must adjust his demands when his cultural adaptations do not sufficiently protect the ecosystem components. If he does not adjust to the ecosystem requirements, he faces the very real possibility that the carrying capacity of ecosystem Earth may catastrophically limit population and/or quality of life.

Against this background, we will trace species man as he developed new sets of relationships with his encompassing ecosystems.

Man, the Natural Species

In man's first ecological stage, his impact on the ecosystem mechanics appears at a level consistent with the other species of his communities. Prior to development of cultural techniques that would allow him to systematically locate and increase control over food production, he occupied a natural ecological niche. He gathered existent plant supplies, employed rudimentary tools to kill animals, and extended his range of habitation to a minor degree by elemental protection devices. As a natural species augmented by minor tools he was a dominant species in local ecosystems, but his influence on environmental carrying capacities were similar to the effects of other species. His demands were elementary and primarily within the food cycle; functional specialization was minimal; there were no artificial demands on usage of ecosystem elements. Population was controlled by natural processes; dense population centers were nonexistent. If environmental damage occurred in a locality, man's inability to modify the damage in the short term caused him to reduce his effect by immigrating, thus allowing natural repair to occur.

Man, the Farmer

The development of crop-culture and animal-culture by man allowed a dramatic change in his relationships within his ecosystem communities. Selective development of artificially-maintained species plus improved control over the ecological niches of competing animal species allowed man to dominate his communities. Ecosystem disruption was caused by cultivation using artificial plant patterns that increased the utilization of local nutrient pools and caused erosion. Introduction of planned food production - whether crops or domesticated animals led to increased localized population densities and allowed the support of a larger human population within a locale than had been possible. Rudimentary specialization appeared--huntsmen, farmers, tanners, clan chiefs--allowing improved utilization of labor resources and technological information.

His ecological niche was significantly enlarged. In his communities, man became dominant among competing species and, through technological adaptation, he extended his habitat significantly. Population, although still limited by many natural elements, depended less on occurrance of food since man could both produce and store foodstuffs. His capability to damage an ecosystem was expanded but, due to his low mobility and the limited extent of his artificial controls, damage in large land areas was minimized. A major new factor, however, was growth--increased area population and increased demands per capita. The increases in demand also involved increased demand of the products of specialized functions, such as pottery, a dramatic innovation from demand for food and protection. This last element, in particular, blossomed in the next stage because this stage, with its rise of per capita agricultural productivity, released portions of the population from subsistance employment. Man's unique ability to retain culture allowed development of, and demand for, "artificial" products and services not required as part of his natural functions.

Man, the Specialist

The ability to produce and store food surpluses increased stresses for man as well as the environment. As he acquired, stored and consumed larger amounts of possessions, questions of shelter, trade and defense became more important. Permanent settlements began to appear, partially because of the realization that many of his production functions could best be undertaken collectively or by specialists in the community.

The growth of settlement from centers for the appropriation and redistribution of food surpluses into more complex cities was hastened by a growth in social awareness. Permanent settlements provided an attractive medium for the free exchange of ideas. In an atmosphere conducive to innovation of products and division of labor, collaborative efforts extended the zones of settled life into areas beyond initial centers of agriculture. As newer farming techniques involving irrigation, plowing and rotation came into being, previously "marginal" areas for habitation become more desirable.

Man, in pursuit of a new set of needs, improved his capability to control the natural conditions of his localities. He introduced higher productivity capabilities and introduced new processes well outside the natural food chain processes. The new specialized functions often improved his natural defenses against predators and natural cyclical disasters.

While study shows damage to limiting factors of local ecosystems increasing over previous stages, the development of mobility and social mechanisms for goods redistribution expanded the reaches of applicable ecosystems. Hence, these initial social and economic practices continued to develop under the assumption that the ecosystem had practically unlimited resources - system carrying capacity was of no practical concern. It is interesting to note that this period also gave orders- o-f magnitude increase to artifacts of manufacture that were not naturally recycled.

Man, the Technologist

The development of energy converters together with the blossoming cultural innovations that initiated the industrial revolution drove man, as a manipulator of his environment, to a significantly different niche within continental ecosystems. The social and economic patterns became increasingly specialized; urban forms become more dense and more numerous. Productivity per capita in the highly developed countries drove goods consumption well above subsistance needs and toward desires for more and more specialized products. The entreprenurial spirit and rapidly expanding capital and technological bases allowed a multiplicative increase in goods availability and distribution. It also produced the development of a social structure that would consume the ever increasing diversity and levels of nonessential goods. Growth became the keyword to measure the goodness of man's social and economic systems - growth of population, growth of industrial output, growth of material consumption.

Unfortunately, growth also occurred in other areas of human ecosystems. These include intensified population densities in local areas and in the total system, rapid use of resources in processes that do not include appropriate decomposers, and increased byproduct effluents deposited into the environmental media. Man has achieved such dominance by his technology that he can modify nearly any ecological process for short- term gain.

The general laws of ecosystems remain inviolate, however, and the widespread occurrence of dense populations has forced reconsideration of the fact that the ecosystem resources and media are not unlimited. Many of the limiting factors of the regional ecosystems appear to have been reached in large localities. Some of these limiting factors can be adjusted by redistribution, but many; such as environmental media, elemental energy processes and land; cannot be relocated. The widespread signals of ecosystem damage under the imposed social value structure of highly developed nations leads us to reconsider the value of growth. Man the technologist has driven man the social organism to high demand levels and provided biological protection that permits rapid population growth. But he has not devised a mechanism for guaranteeing continuation of his regional ecosystems as resilient, stable entities in which growing human populations can maintain a stable, dominant niche while increasing their resource usage demands.

Man, the Ecologist

As the ecosystems send out their first powerful signals of imminent damage to the environment's carrying capacity, the social structures of man are attempting to determine the levels of societal redesign that are needed to balance man's habits and demands within the regional ecosystem's processes and resources. A major element for redirection is the redefinition of acceptable growth patterns under the assumption that the species size and demands are approaching the ecosystem's renewal limits. Many new concepts, antithetical to the concepts of the industrial revolution period, are proposed - zero population growth, stewardship of goods and resources, alternative lifestyles, return to simpler forms of society.

But the new awareness and willingness to modify society's goals are not sufficient; there is a need for development of mechanisms for evaluating the costs and benefits to the ecosystems caused by alternate proposed solutions. A major question for any region is: what new social and economic technologies are necessary to maintain acceptable qualities of growth within stable ecosystem carrying capacities? A major corollary to that question is: for a given pattern of growth, what are appropriate quality of life demands to maintain man as a dominant, stablizing element of regional and national ecosystems?

THE LINKS BETWEEN THE HUMAN SYSTEM AND THE ECOSYSTEM

The attributes of the natural ecosystems have been discussed in detail including the concepts of carrying capacity, resilience and stability. An essential ingredient in the vitality of the system is that the limiting factors to growth within the ecosystem are not overused. If overutilization occurs, the system suffers stress and undergoes change.

Readjustment of the ecosystem can be accomplished in several ways. In the simplest case, the stress is only temporary and a short period of adjustment will return all of the system characteristics to the previous equilibrium. A more severe trauma may cause some redesign of the system characteristics resulting in a new state of equilibrium with some adjustment to the carrying capacity likely. The trauma can be, and in historical cases, has been enough to severely damage the system, causing a sudden degeneration to a very different ecosystem equilibrium that has much lower levels of carrying capacity--equivalent to the creation of a media-desert.

Man's present relationships to the natural ecosystems include the capability to completely dominate large regional systems. In doing this, he determines for at least the short-term the level of consumption or utilization of the regional limiting factors. If man demands too high a use of any of these factors for too long a period, he may produce damage to the encompassing ecosystem--pollution of media, lower plant growth due to resource shortages, starvation, too many domesticated non-food animals, etc. In each case, man and the other species of the regional community have passed the natural and technological capabilities to provide increased quantities of limiting factors of the human and natural ecosystems of the region.

The limiting factors for human ecosystems are akin to the resources that technology and agriculture transform into man's products. They are not limited, however, to the more classical definitions of resources applied in manufacture but include all limiting factors of an ecosystem that can be affected by man. Thus, we must include as generalized resources the media of the ecosystem--air, water and land--labor, and capital, as well as crops, ores, and fuels.

Measuring Population Demands

Prior to definition of a tool to study growth within a large ecosystem, this paper will next describe the forms and utilization of these generalized resources relative to the demand of the dominant population.

The demand here is made up of two elements:

- The number of consuming units - a factor related directly to population size, and
- The size of the demand unit - a factor related to a per capita demand for level and quality-of-life style.

The measurement of the per capita demand level is, in the present state-of-the-art, a rudimentary mechanism. While research continues for the development of composite indexes akin to the much less complex set of economic measures used as diagnostic tools for regional economies, much remains to be done. In the SOS Model a procedure for utilization of a family of region-specific demand measures is provided, thus obviating the need for predicting adjustments using a single scalar value. However, later refinements of the model may suggest need for specialized use of such a scalar combinatorial measure; Appendix 1 of this paper discusses one such procedure.

SECTION IV

RESOURCES OF THE HUMAN ECOSYSTEM

As suggested in the proceding section, the carrying capacity of an ecosystem is greatly influenced by the availability of resources and the manner in which they are utilized, primarily by man. Thus a key element in the State of the System (SOS) Model is the treatment of resources availability and utilization. This section presents the concepts upon which the model's simulation of resource consumption is based.

To illustrate the danger of prophesizing with absolute certainty, review this outlandish bad guess of the past:

> It will soon be sixty years since Gifford Pinchot published The Fight for Conservation, as informative and succinct a guide to the Conservation Movement's views and judgments as one can hope to find. With regard to resource adequacy, it presents a generally somber picture, supported by careful projections based on the idea that the volume of economic resources in the United States is defined by their identified physical occurrence. The lesson that only careful husbanding can stretch the supply is the logical sequel. Governor Pinchot summarizes the findings of approaching resource exhaustion as follows: The five indispensably essential materials in our civilization are wood, water, coal, iron, and agricultural products . . . We have timber for less than thirty years at the present rate of cutting. We have anthracite coal for but fifty years, and bituminous coal for less then 200. Our supplies of iron ore, mineral oil, and natural gas are being rapidly depleted, and many of the great fields are already exhausted.(16)

Optimistic resource projections normally include a fair measure of increased technology expectations, a good world-trade picture and an adaptive organizational structure. Even the optimistic writers admit of the likelihood of short-term dislocations and that some of these short-term problems will cause over-reaction by those affected. Two of the anticipated contributions of the SOS model are the attempt to develop changes in availability through substitution of resources using combinations of similar resource types and by taking into consideration the discovery and delayed development of new areas of resources based on the existant resource extraction prices. A third, less positive contribution is the SOS model capability to over-react, in some cases driving the system to a greater crisis in other resources.

The idea of ecological accessability as a limitor has meaning in developing data to represent the resource constraints. Because resources are not distributed equally across the Earth, the insulation of a society or a nation from catastrophe is a function of its access to scarce resources of production. The access can be provided by ownership or by trade; the latter course is less secure over the long run.

In summary, the availability of resources at any particular time is the result of the interactions among the nature and size of man's requirements, the physical occurrence of the resource, and the economic means of extracting or producing it. Estimates of future availability of resources, therefore, require the assessment of:

- The particular combination of economic and technological conditions that determines present production,
- The level of production that would take place under different economic conditions caused by scarcity,
- The level of production that could take place under different technological conditions, and
- The nature and quantity of the total physical-existant stock of both "renewable" and "nonrenewable" resources.

RESOURCE DEFINITIONS

Because the relationships between these physical, human and economic variables are complex and vary with time and place, views concerning future supply need to be carefully expressed and set in a context such as the threefold hierarchy of total stock, resource, and producible reserve. These concepts are summarized below from the work of Lovejoy and Homan (1965), substituting the term total stock for their use of resource base.

> Total stock is the sum of all components of the environment that would be resources if they could be extracted from it. Assessment of the total stock is largely the concern of earth and life scientists, and the state of knowledge concerning it depends on the adequacy of prevailing theory, the state of exploration and survey technology, and the extent of its application. Applied to what are conventionally referred to as nonrenewable resources, the total stock is finite and thus eventually exhaustible. Applied to renewable resources, the total stock consists of

highly complex systems in a state of dynamic, delicately balanced, and only partially understood, equilibrium. Resources comprise that proportion of the total stock that man can make available under technological and economic conditions different from those that prevail. The assumed state of technology will set the limits within which different economic and social variables [will] determine what proportion of the total stock can become available. Assessment of a resource [level] involves not only physical and biological scientists but applied and social scientists as well. They must make judgments: about the directions and rate of change of technological developments (e.g., gradual increase of efficiency of extraction of a mineral deposit or yield of a crop as against dramatic, order-of-magniture, breakthrough changes); about the impact of changed economic conditions and new alignments in international relations; and about public attitudes on such varied matters as birth and population control, transportation preferences, and clean air. In essence the question is one of judging man's potential for creating resources out of the total stock; of selecting the chief agent of change from among technological, economic, or other societal forces; and of determining the relevant time and space dimensions. Reserve refers to that proportion of a resource that is known with reasonable certainty to be available under prevailing technological, economic, and other societal conditions. This term embraces current extraction rates, yield, management practices, legal frameworks, and social attitudes. It is, therefore, the least speculative, shortest term, most place-specific, and smallest of the three types of estimates.(17)

These three concepts provide a framework into which each of the many estimates of resource availability may be fitted and thue be seen in perspective. By providing a rationale that accommodates what often appears to be starkly conflicting professional opinions, these concepts reduce the ground for misunderstanding, overoptimism, or undue pessimism. Furthermore, they incorporate the notion of resources moving from one threshold of availability to another in response to changing values of variables under human control, allow estimates to be made based on physical or economic assumptions, and yet permit retention of the essentially "physical world" character of the materials involved.

GROUPING RESOURCES FOR THE SOS MODEL

The State of the System Model essentially follows the traditional definitions of resources used in manufacturing and services. Along with the traditional list of six resource groups, the model includes two resource-like groups to permit consideration of the level of damage caused to the environmental media of air and water. Thus, the model treats the eight resource groups:

- Energy sources
- Natural resources (durable ores)
- Agricultural resources (food and fibers)
- Land
- Workers
- Capital (including R & D funds)
- Air
- Water

The eight groups can be divided into the categories of nonrenewable resources - natural resources and energy sources - and renewable resources - agricultural goods, land, workers, capital, air and water. These two general categories and each of the eight resource groups are discussed separately below.

Non-renewable Resources

The two groups that usually provide their primary reserves as ores represent a resources category that, when viewed in the long run and under pessimistic technological projections, can quickly suggest a dismal future for the regional ecosystem as these ores are exhausted. However, even if they are non-renewable--which for neither ores or energy sources is totally true--several hedges exist for prolonging the resource and for reducing its role as a critical production resource--as an ecosystem limiting factor.

Non-renewable resources are treated in the SOS Model using the following viewpoints:

- All resources are measured in terms of the total stock as defined above. Hence the maximum ore limit is not a function of economics, but is a much larger physical value inherent in the ecosystem.
- The total amount of world resources available at any time (the reserve) is finite and less than the

total stock. The amount is a function of processed stock-on-hand supplies plus time delays for extracting, recycling and distributing the ores that economically qualify as reserves under present processing costs.

- The total amount of resources available to a region has an upper bound based on considerations similar to those above plus the maximum import potential as reflected in existing ownership and trade arrangements.
- If a resource mixture that can substitute for a critical resource exists, or if a technological improvement in production reduces the requirement for a resource, the production sectors undergo significant time lag and capital expenditures as part of reactive retooling. Because of the inertia in the processing changeover, these changes will be made only when a resource depletion warning is reached. This warning system of possible resource shortages acts as an alert to all production components simultaneously.

Energy

Since energy cannot be stockpiled in its processed form, the amount of energy produced for a given time is a function of past and projected demand. The selection of the specific sources of the energy that will be consumed are based on minimization of cost of an energy unit and the system propensity to maintain status quo of sources and processes. Therefore, the mix of energy sources used to meet the demand will remain relatively fixed unless a shortage in one or more fuels or conversion methods is imminent. Although, theoretically, signals for imminent shortages could be based on stock levels, it is considered that the better signaling device in energy (and in the other resources) is the current cost per processed unit. Note that most of the present energy crisis discussions in the United States have not been centered on the total stock level but on the facility construction times and increasing costs of extracting and distributing the resource fuels using methods that are acceptable to the population.

When shortages are signalled, the SOS system will attempt to adapt by substituting one or more energy sources for the problem one(s). The new mix of energy sources must satisfy the constraint of lower mean unit cost (equivalent to improved fuel reserve availability levels) to be an acceptable substitute. Additionally, the system will check to determine if the present sales price for the critical resource ores is sufficient to expand the stocks that can be classified as reserves.

Substitute energy sources can be of many forms. They can be of the form of substituting among currently used resources in new utilization mixes, or the use of a relatively new source that now becomes an economic alternative. For example, two of the more popular new sources in today's discussions are solar and fusion energy. Both are currently under intensive study and the results, from the experimental and prototype uses, run the gamut from very hopeful to hopeless. In the technological areas, changes to the energy supply picture could come about from several directions: from new forms of energy conversion; from more efficient application of today's technology; from new sources or better extractive methods; and finally, from new types of applications.

The concepts developed here for increased stock availability of a particular resource due to changes in the economics of extraction and of substitutibility of other resources are relatively unique and, until further analysis, should be reviewed with some skepticism. For example, most of the better-known estimates of energy ore availability are highly price-related. This consideration results in different estimates of reserves based on assumptions of changing demand for goods and services coupled with assumptions of minor institutional and technological change. The results of this perspective have been a consistant under-reporting in absolute amount of resources available as energy reserves and the concommitant crisis figures often reported from a mapping of price-related reserves against population growth.

Similar anomalies are present in the consideration of substitution among energy sources. It is obvious that price alone will not determine substitution but that habit, legal constraints, media pressures and the like might influence the time of change to be either long before or after the time of substitution as dictated be economic indicators. Consequently, a model of the substitution processes will be quite complex in the final analysis. Of course, surrogates of energy usage in production processes are available from analysis of fuel changes in industrial, commercial, and residential uses as extrapolations over time, but such regressions should be viewed only as stopgap expedients and fragile in terms of meaningful long run analysis. Due to the present set of crisis for several fuel types, it is quite likely that significant departures in mixes of fuel sources will occur.

This viewpoint becomes even more likely when the side effects of energy ore mining and energy consumption on the environmental media are noted. There is a positive corrolation between energy/capita utilization and the level of industrialization; thus, sincere trepidation of likely effects of energy needs and of energy consumption rightfully exists. The SOS Model considers all affected resources and uses a set of adjustment procedures similar to those being affected by the U.S. planning community.

Natural Resources

Natural resources, like energy, are normally viewed as a non-renewable reserve category. Like energy, there are several practical hedges in setting or expanding the actual stock reserve at any one time. For many resources, as the unit costs for extraction and distribution of ores increase significantly, new levels of stocks can be converted from the resource category to the reserve category--the economically feasible stockpile. Second, for many of the ores there is a high level of substitution of other resources in specific production processes. These substitutions can be caused by technological improvements or simply a trade-off of one ore for another similar material. This second process is treated in the SOS Model by substitution within resource strata, and the resources within the natural ores category are assumed to have several strata. Examples of strata include trace metals, structural metals, non-metallic minerals, etc.

Another conservation device available to natural resources that was not available to any great degree in the current primary energy sources is the ability to recycle ore from debris from processed and consumed industrial goods; a procedure similar to natural ecosystem decomposition procedures. This procedure, tempered by the mobility of the various component products in passing from ore to goods to debris, sets a natural ore reserve with a size that is once again variable by cost, here the recycling cost. The comparative levels of recycling costs to extractive costs will determine the level of ore salvage from the system debris.

Review: Non-renewable Resources

In the discussion of energy and of natural ores several caveats must be applied to the definition of non-renewable. For both energy and natural resources there exist mechanisms to extend the level of usable reserve beyond the static reserve levels of the resource. This does not imply that the production process allows total recapture of the resource ores after a time delay, but it does suggest that through mechanisms such as technological improvement in energy conversion and improved ore recycling procedures as extraction unit costs increase, the present resource horizons for non-renewable resources may be unduly pessimistic. The SOS Example Model will include three resource adjustments for ores: substitution, expansion of economically extracted stocks, and resource recycling.

Renewable Resources

The remaining resource categories have their reserves limited at any time but are considered renewable because procedures to recycle the resource presently exist and have been demonstrated. A major problem for many renewable resources is the ability to expand the reserve level consistant with the expansion of demand. Even where expansion is possible, system inertia often causes a several year delay.

Land

Within a given region the total amount of land does not significantly change. While it is possible to create some new acreage from surface water areas or to lose land due to erosion, the relative change in total land form is judged insignificant for consideration at the total stock perspective. However, these special land generation sources, when its specific utilization or worth characteristics are viewed, may require consideration due to its high intrinsic value to the local population.

The land resource can be subdivided at any point in time by its expected near-future usage. Six land usage categories might be considered:

- Residential
- Industrial
- Commercial
- Agricultural (including pastures and non-recreational forests)
- Recreational
- Other (i.e. not falling into any of the above categories)

The distribution of the total resource reserve among these use categories can change based on the magnitude and priority of the demands in the various categories. Additionally, for at least the first four categories, land utilization can be intensified by use of other resources in the production process (e.g. urbanization or greenhouse densities).

In terms of U.S. land use for development (as opposed to agriculture, recreation or other) the land resource is presently seen as limited only in ecological distance. Over the whole of the United States, about three percent of the total land area is devoted to developed uses; the percentage has not been increasing extraordinarily rapidly even in the face of historical major increases of population densities in and around our urban areas during the past 30 years. The problem of ecological distance (or accessibility) is handled in the model by considering the relative utility of the land reservoir around urban areas in terms of combination of aesthetic, topographical, and transformation costs. By this procedure, a capability to increase land availability in each use category exists and is governed by two factors:

- The total reserve of all usable land
- The present unit costs to transform and maintain land as compared to the present accepted land use earnings.

Thus the concept of substitution of similar resources for scarce materials exists for land--subject to payment of the costs of transformation are paid and reduction of the reserves of the land use category from which the substitution is drawn.

Agricultural Resources

If we were to be concerned with the issues identified by others who have researched in the field of resource availability, a great emphasis should be placed on the agricultural portion of the resource base, more specifically, on its output--food and fibers. Because a nation must first meet the subsistance requirements of the population, the first resource of major concern for a region is the availability of adequate food and shelter.

In America we have land in abundance but it is not of consistent quality. Differences in soil quality, climatology, topography, etc. affect the soil's natural capacity to yield food. These problems have not been critical since, added to the abundance of arable land in the U.S. there is a huge scientific and technological superstructure which has produced startling argicultural increases on marginally arable land while decreasing inputs of land and labor. However, it is by no means sure that this fortunate circumstance will continue as worldwide demands continue to grow and other land-use and environmental conservation demands are met.

Production of food can be increased in the U.S. and many other areas by five principal methods:

- New lands
- Enhanced productivity of presently cultivated land
- Prevention of loss (of tithing to rats, fungi, and insects)

- Innovation, and
- Change in the economic base.

Some projections suggest that the need for both additional acreage and farm output per acre will occur in the next few decades, as the per capita food consumption rates continue to increase or stabilize and as the population grows. Furthermore, the amount of the limiting total stock base (the land) available for this use will be a function of relative price among competing land uses. In fact, some of the most fertile land is presently under concrete.

There is a growing need for forest products, but conservation actions of the early twentieth century to assure the supply of forests has made this demand less critical in the short term. In essence, the future needs and production of food and fiber can probably be regulated through the price mechanism. However, the rapid escalation of today's market-place food prices suggest that some painful supply dislocations in this area exist even now due to inertia in changing production levels.

The possibility of food from the sea has been mentioned often as a major "agricultural" source in the future. The limit appears to be much lower than is popularly assumed. Large tonnages of fish catches or sea-cultured plants and animals do not appear to be available quickly or inexpensively. Further, it is not clear what heavy fishing will do to the carrying capacity of world's fish supply. This very important source of protein is under study in many nations where dependence on foods from the sea is greater than it is in the United States. Although the sea is certain to continue to play an important role in the world's protein supply; it is clear that, for the reasonable future, the harvest rates of sea-culture will not increase significantly.

Hence, the likely procedures for increasing resources now primarily obtained by agriculgure are:

- Expansion of cultivated arable land
- Intensified yields/acre by increased use of other resources (use of chemicals with increased toxic runoff or large-scale greenhouse production of plants)
- Substitution of manufactured structural materials and fibers for cellular materials and animal fibers.

Thus a new set of mechanisms for increase of the animal production of the reserves of foods and fibers exist different than those noted for ores and energy. In the first two of the three procedures above the available resource stockpile expands not by increasing the existant extraction procedures or by general substitution of one similar resource for another, but instead demands a change in basic agricultural input/output procedures. In later sections of this report, appropriate procedures are defined for SOS as part of the agricultural production process. However, to obtain this needed model capability one of the private industrial components that includes growth must be agriculture. Further discussion of this consideration is found in Section 7.

Capital

Man-made capital is another resource available to this culture as an intermediate step between raw materials and final consumption. As such it is a vital link in the transfer process and it responds to the same sort of pressures as the other renewable resources. Capital at any time has a definable reserve level, its increase has inertial drag that regulates its rate of expansion. As its value relative to other system resources increases, funds are expended and the rate of capital expansion produces a gain in the existant usable and renewable supply.

Labor

The sixth form of resource used in component production is labor, measured in work units. This resource is directly related to specific population age groups and partitions within the age groups. Like the resources of natural ores, energy, land, and agricultural output, the labor supply is considered to be a function of unit cost, in this case average salaries. Unlike the other four categories the supply does not simply increase proportionately with the unit cost increases. Rather, it has an upper limit determined by population size; the proportion of this maximum stock that becomes the labor supply is assumed directly affected by the cost in production (salaries). While a time lag for increase of the reserve exists, the total stock (the adult population) can be reallocated more rapidly than most resources into a reserve status. However, after this reallocation in done, it is assumed that little additional work unit reserve growth is possible except immigration. However, immigration regulates work unit increases in direct proportion to the total population and total goods demands growth; hence, work unit shortages in periods of high demand can become a systemic characteristic.

Air and Water Media

As has been evidenced in some areas, urbanization and industrialization has caused massive increases in waste product density in the regional ecosystem. A balanced ecosystem will produce no waste; wastes will be, through natural processes, converted to the resources of other system processes. The technologies and densities of human-culture processes can result in unbalancing the system through overemphasis on certain processes that include high generation of by-products or through the development of a set of products that cannot be naturally absorbed and converted to system resources. When these imbalances are created, the production system must be augmented by treatment facilities to reduce the by-products to useful resources of the regional ecosystem. If this is not done any of the several forms of pollution will occur. This pollution of air, water or land may be sufficiently large as to reduce the carrying capacity of the ecosystem media--thus affecting the ability of the system to accept growth, and perhaps resulting in permanent damage to the regional environment and carrying capacity.

Although the ecosystem media of air, surface water and ground water (and to a more limited extent, land) are not, in the usual sense, resources absorbed in production processes and goods; they represent causal resources that can act as ecosystem limiting factors. Our treatment of them will be similar to that of a capital maintenance function--the SOS model requires restoration of that part of the media that is not cleansed by natural ecosystem processes and that is not of a quality that is demanded by the species of the regional ecosystem. This funds are allocated prior to use of operating funds for goods output.

RESOURCE FUNCTIONS

The following general rules can be associated with the SOS Model simulation of all resources:

- The available resources at any point in time can be associated with a unit procurement cost. This cost can be used in a number of model procedures concerned with the detection and the resolution of perceived resource crises.
- At any period in time, the stockpile of a given resource in absolute terms is unknown. However, the quantities available as resource reserves for a given unit procurement cost are known and act as limitors on the regional goods production systems.
- For any resource, the indication of a perceived resource crisis is associated with preset stock depletion warning signals. These signals are set when the present resource stocks no longer can produce a unit of the resource within the current unit procurement cost range.

- The resources of ores, foods, fibers, energy and land have resource strata within the general resource category. Within any strata the mix of associated resources used to make up a single unit of that resource strata is maintained without change unless a stock depletion signal occurs for a resource in that strata.

- If a stock depletion signal for a resource or a strata occurs, a check of allowable substitutions is made to determine if another acceptable resource mix (generally called a substitution) can be made in production processes that generates a lower unit procurement cost. If this condition is met, the substitution process is initiated.

- For any substitution process, increase in economic stockpiles, or change in input/output processes, the full change may require several time periods. The level of attainment achieved for each subsequent time period (cycle of model operation) is calculated and the appropriate level of mixed strategy is used in production processes for that period.

- In addition to the expansion of a critical resource base by substitution, the availability of resource total stocks is checked to determine if the current unit procurement cost will cause a greater stockpile of the resource to be transferred to the reserve status. Such increments are carried out using a time delay function for activating the new reserve sources. Expansion of the resources of land and labor are subject to additional constraints in that:

    - labor must maintain its total population partition structure and,

    - the total amount of land is constant;

  hence expansion of one land or labor strata implies decreases in other strata.

- The natural resources and sub-categories of other resources can include expansion by recycling available ores. The rate of recycling is based on maintaining a minimum unit cost from the complementary sources of extraction and recycling.

- In its present form, the original source of transportable resources (ores, energy, foods and fibers) is not considered. The selection of stockpile levels and increments as a function of the price require calibration to reflect the availability from sources both internal and external to the region.

SECTION V

MODEL OVERVIEW

PURPOSE AND APPLICATIONS

The State of the System (SOS) Model is being developed as a technique to analyze different alternate approaches for melding the growth desires of a population with the limitations of the locale in which the populace exists. To treat this problem, the ecologist's concept of a regional carrying capacity has been used as the basis in building a mathematical model which will constrain the demands of the growth desires to remain within the bounds of the locale's resources. To handle this growth vs. environmental limitations paradigm, the model has been designed to test various assumptions about the desired growth of an area under a set of side conditions (boundaries, constraints, or thresholds) that define the status of the region's limiting factors. Feasibility is demonstrated if the desired growth can be achieved without violating these side conditions.

As examples of candidate side conditions, the model would translate higher level laws and regulations (federal and state, for example, if the model is of a local government), health thresholds, natural media limits and the local desires into quantitative side conditions. For example an analysis could include values for a minimum level of subsistence per family, a maximum regional unemployment rate, the various environmental quality standards, housing and other industrial-commercial codes, density levels and minimum education levels. From these boundaries and the resources of the region that can act as limiting factors, analysis of feasible growth levels could be made.

Implementation of this model would result in the ability to test both the present growth trend and apparently desirable variations. Alternatively the relative impact rates of less desirable variants could be analyzed.

Such a model could be used to analyze at least three types of questions. First, it would be able to test the ability of proposed growth trends to arrive at the goods of the locale over time as defined by a comprehensive plan. As a tool within a second analysis form, it could allow the user to test the probable life of a system operating within the constraints on growth and discover the most viable and critical linkages and constraints, given the resources of the locale and the constraints as set in the initial conditions. Finally, analyses similar to the two above could be run that use several different policy alternatives as starting points or adjustment mechanisms. Such analyses would determine the relative utility of each alternative.

STRUCTURE

The State of the System Model includes four major ecosystem structural elements:

(1) Sectors of Growth. This consists of three components: the population, measured in terms of physical needs - i.e., as consumer demand levels; the private production sector; and the public services sector. The form of population demands have two elements, population size and increasing per capita demand levels. The two latter components are each measured in terms of annual change in level of expenditures for maintenance and production (M & P) funds. The private production sector and the public services sector, each, can be subdivided into component categories (e.g., heavy industry production or educational services) with each category being an independent growth component of the region. While the population growth is not divided into components, it is partitioned into special need groupings in response to the relative levels of output being produced by the components of the private and public sectors.*

(2) Production Component Output. This system element refers to the outputs of regional economic and government production systems during the period which are available for regional consumption. Net export levels are also accounted for within these outputs as governed by the regional demands for outputs.

(3) System Limiting Factors. These are of two major forms; the input limitors are made up of resource availability and of ecosystem support-media treatment requirements; and the societal constraints representing present demand levels placed upon private and public sector output to maintain an acceptable (or desired) level and quality of life (QOL) for the present population size.

(4) Long Term Goals of the Society. These provide, at a minimum, the lowest values of level and quality of life measures that the society will accept as steady-state demand levels. From this minimal statement of society goals, the basic planning mechanism and demands of the society can be introduced into the model by having the demand constraints become increasingly defined and restrictive up to and including exact and comprehensive regional production plans (the long-term equivalent of a planned-economy five-year production plan).

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*In the discussion these components are often called production components where production may be in goods or services. For SOS, the use of sectors denotes the public and private investment categories.

The interaction of these four model elements is illustrated in Figure 3. The state of the system (the regional description) at any point in time includes the results of the growth projections and the estimate of output provided by each of the regional production components. After this description is provided, an analysis of limiting factors on the production output is made, determining apparent shortages in resource availability or deficient quality in ecosystem media. The model also determines short run failures of the system output in meeting level and quality of life demands of the system population.

The failures and shortages of the system set into operation a set of regional subsystem adjustments to achieve short-term and long-term adjustments within the system. These adjustments are then compared to the long-term societal goals to determine if those production and resource availability adjustments appear sufficient to provide attainment of long-term goals or, alternatively, to determine the extent to which the regional population must relax its demand levels. The forms of adjustments are discussed later in this section.

For those most comfortable with modeling techniques, the model can be described as one where side conditions are set by the user or designer and within these bounds the model is driven by goals of public and private growth. The side conditions can be visualized as a membrane defined by the limiting factors set by the ecosystem's ability to support the needs of the population. In this case, the model groups the limiting factors as natural resources and demands for quality of life. If a side condition is not met this will stretch or rupture the membrane (violate any parameter threshold in the set of minimum limits). When and if such a stress or rupture occurs, the model feedback controls attempt to correct the regional stress in ensuing time periods by introducing policies which would bring the demand trend back within the membrane or will relocate the membrane by updating the limiting factors.

ASSUMPTIONS AND SIMPLIFICATIONS

Since the model is expected to be operated as a regional model--where the region is national or subnational--the system does not have a high degree of closure. Hence the model must account for trade arrangements and other primary exogenous forces. At this point of the model development these questions are neglected for the most part. They will be considered in appropriate detail in the model formulation and data base discussions later in the paper.

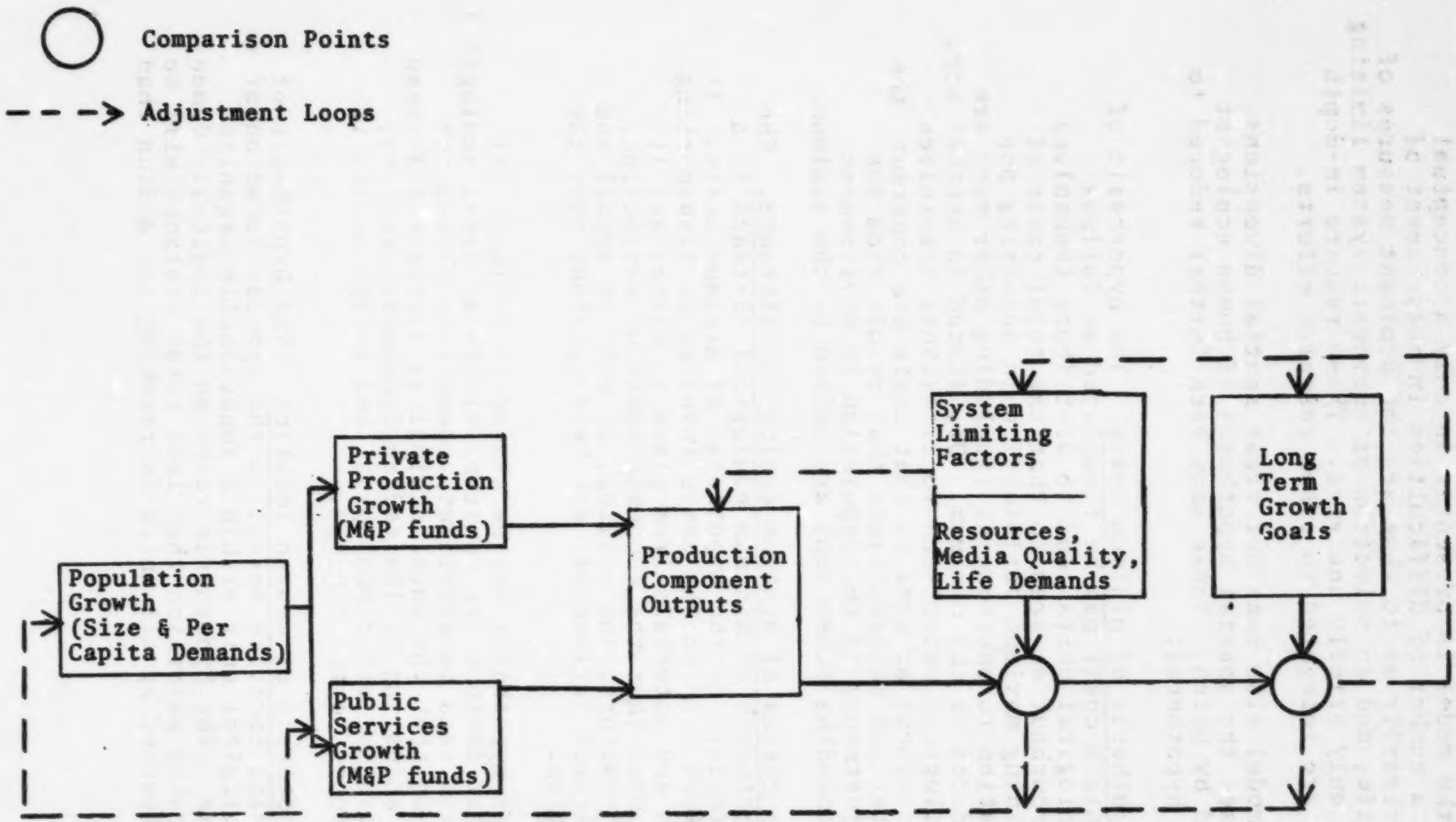

Comparison Points
Adjustment Loops
Population Growth (Size & Per Capita Demands)
Private Production Growth (M&P funds)
Public Services Growth (M&P funds)
Production Component Outputs
System Limiting Factors
Resources, Media Quality, Life Demands
Long Term Growth Goals

FIGURE 5

CONCEPTUAL FORM OF THE STATE OF THE SYSTEM MODEL

Also, since the model is presently in only a conceptual formulation, a number of difficulties in measurement of variables, primarily as to what are the dominant measures of quality of life, and in selection of surrogate system limiting factors, are only briefly analyzed. These require in-depth analyses and are relegated to other research efforts.

The present model also does not treat spatial dimensions. Rather, it uses the spatial hypotheses of human ecologist as summarized by Quinn. These have been further reduced to four general hypotheses:

- Hypothesis of minimum costs. The hypothesis of minimum costs may be formulated as follows: Ecological units tend to distribute themselves throughout an area so that the total costs of gaining maximum satisfaction in adjusting population to environment (including other men) are reduced to the minimum. Or, stated in another way, ecological units tend to distribute themselves throughout an area so that costs are constant, the total net satisfactions that result from the adjustments of the population to environment (including other men) are raised to the maximum.

- Hypothesis of minimum ecological distance. The hypothesis of minimum ecological distance is a corollary of the hypothesis of minimum costs. It refers only to the costs involved in transporting men and materials from place to place; and it assumes that the economic costs of extraction, manufacture, and selling, as well as social and cultural influences, are held constant over the region.

  This hypothesis may be stated as follows: If other factors are constant within an area, ecological units tend to distribute themselves throughout it so that the total ecological distance traversed in adjusting to limited environmental factors, including other ecological and social units, is reduced to the minimum.

- Hypothesis of median location. The hypothesis of median location refers to the spatial location of an ecological unit within a functionally organized area. The hypothesis rests on the logically demonstrable assertion that less total distance will be traversed by all units in reaching the median than

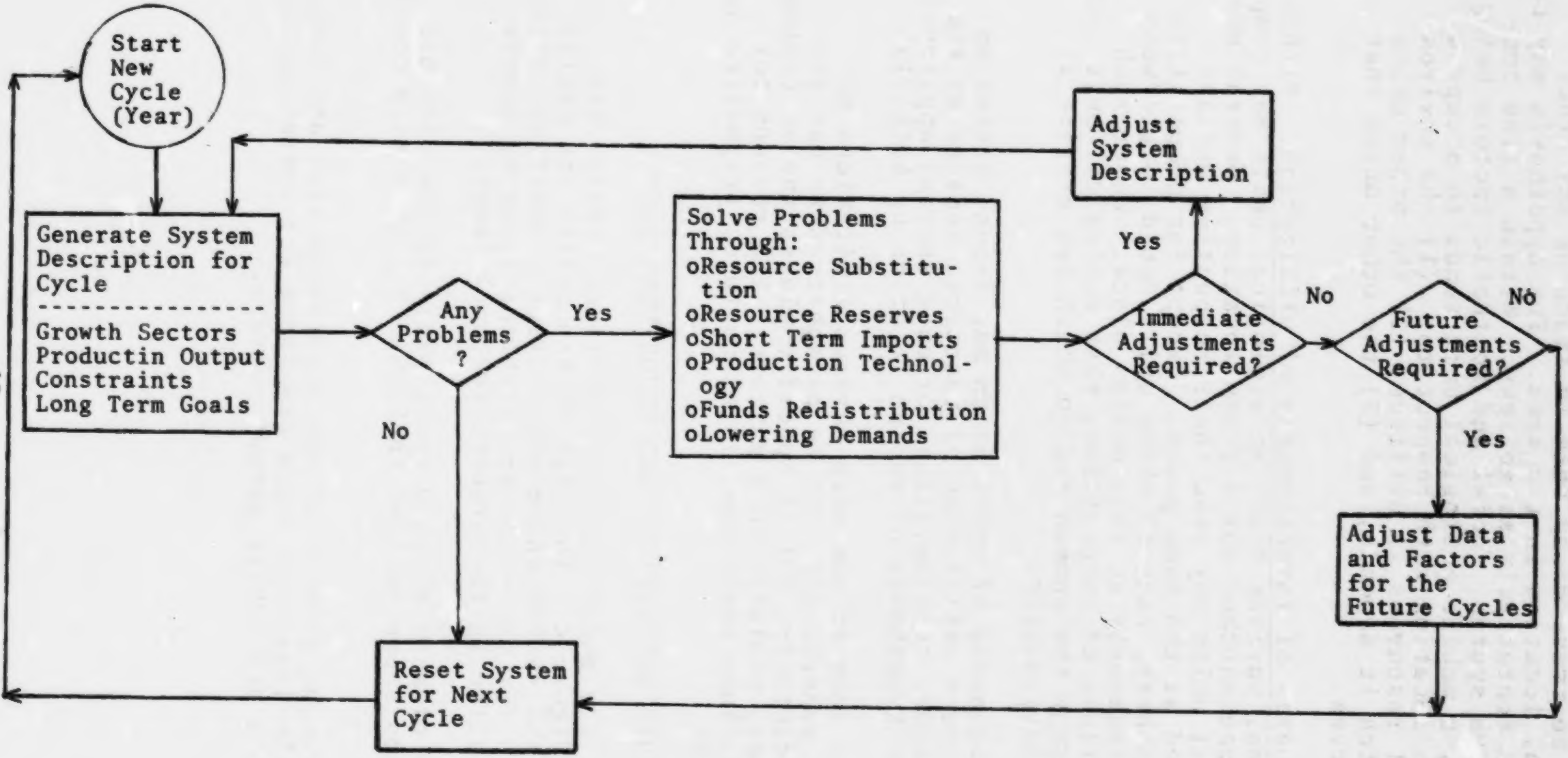

Start
New
Cycle
(Year)
Generate System
Description for
Cycle
Growth Sectors
Productin Output
Constraints
Long Term Goals
Any
Problems
?
Yes
No
Solve Problems
Through:
oResource Substitution
oResource Reserves
oShort Term Imports
oProduction Technology
oFunds Redistribution
oLowering Demands
Immediate
Adjustments
Required?
Yes
No
Adjust
System
Description
Future
Adjustments
Required?
No
Yes
Adjust Data
and Factors
for the
Future Cycles
Reset System
for Next
Cycle

FIGURE 4

MODEL PROCEDURAL FLOW

> would be traveled by them in reaching any other spatial location in the area. The hypothesis may be stated tentatively as follows: Within a free competitive system, social and aesthetic factors being equal, a mobile ecological unit tends to occupy a median location with respect to: (1) the environmental resources it utilizes, (2) the other units on which it depends, and (3) the other units that it serves.
>
> Hypothesis of intensiveness of utilization. Within an area, various types of ecological units may compete with one another for a given location. Several ecological units may find their respective medians located at the same place. Except for competition with others, each of these units could locate most advantageously at this median place. Under such conditions of competition, that ecological unit tends to occupy the common median which can utilize it most intensively.
>
> Intensiveness of utilization may depend either on the direct utilization of resources located at the site under consideration, or on a special application of the hypothesis of median location or both.(18)

Quinn recognizes some of the more obvious limitations on these laws. In general they can be paraphrased as man generally acts predictably, but in specific places and at certain unexplained times, violates this pattern. The reasons for the deviation include tradition, local culture, prejudice, and accidents of time.

ALTERNATE SYSTEMIC DESCRIPTORS AND ADJUSTMENT LOOPS

The dynamics of the model structure outlined earlier are expanded on in Figure 4. That figure emphasizes the cyclic descriptors of the system which are routinely modified, either by cyclic growth (if there are no "problems"), or by ecosystem adjustment reflected in the problem feedback loops.

The descriptive element of each cycle projects the elements and relationships shown earlier in Figure 3. This step consists of:

1. Projecting growths of the population size and demands, and the levels of funds available for operating the private and public output sectors.

2. Generating the expected levels of goods and services outputs for each component of the private and public sectors.

3. Determining status of resource depletion, quality of ecosystem media, and the level and quality of life measures.

This procedure describes the system status annually in terms of the regional carrying capacity--the ability of the regional output production to meet the demands of a growing (or stabilized) consumer population under the constraints and limitations of both resource availability and maintenance of environmental quality.

If the status of the regional carrying capacity shows one or more demand measures indicating short-term failures, the systemic element of the model is entered to determine if the system adjustment capabilities over the short-term or in the long-term can relieve the failures; or, alternatively, can successfully alter the population demands. This portion of the model can, but need not, be cognizant of regional planning processes. Hence, the adjustment forms can be of several types to reflect the intensiveness of regional management.

Thus the model can consider fully planned societies that attempt to meet detailed preset comprehensive output plans, or, at the other extreme, laissez faire or natural systems that require only societal maintenance levels that reflect minimal regional life-support as growth and demand thresholds. Two regional processes will be discussed below as examples; these are the two processes most likely to be considered for applying SOS to analysis of regions of the United States as resilient and stable ecosystems.

The Comprehensive Planning Procedure

One useful environmental planning system is an extension of many past study efforts carried out as municipal and regional planning studies. This system is characterized by the specification of a comprehensive plan that reflects prediction of long-term growth sector demands. From this an objective function is derived that is expected to be realizable. Included in the adjustment methods is a procedure that attempts to perform an overall system-optimization that will maximize the objective function based on the information generated in the model operation up to that cycle.

The set of adjustments are put into operation primarily because of the status of resource stockpiles for the particular cycle. The resources are available at discrete points in time; thus some shortages may be localized or time dependent, not necessarily reflecting a permanent resource depletion but, perhaps, only inertial drag in expanding extraction methods as reaction to new growth demands. Thus, the management system can react to warning signals and "brownouts" by affecting adjustment over the short and/or the long run.

If the projected output of the system is maintained within the regional carrying capacity by simple adjustment of short run supply factors, no long-term adjustment of system demand levels or of sector growth rates need be made. Otherwise, the projected grwoth rates and/or long-term demand requirements will be adjusted based on maintenance of minimal degradation of the objective function. The system description procedures will then be repeated to determine if the new output projections are within the carrying capacity limits of the regional resource allocations and environmental requirements.

An operational model depicting the regional goals as a comprehensive plan or as the more typical operating system can be used to analyze the value or practicality of the plan based on the type analysis that is to be performed.

If the analysis is a capability study of the ecosystem without regard to a prescribed time limit, then an initial set of growth rates for the three growth sectors can be set. The model will then be operated to determine the timing and level of internal system adjustments that are required to the individual growth rates in order to maintain the system in a regenerative form, or alternatively to extend the time frame of the ecosystem as a viable support system.

Alternatively, for a given time span and as a requirements study, the levels of the output required at that ending time can provide trend lines to indicate intermediate values to which the outputs generated each time period can be compared. This annual comparison determines what and how much demand levels and growth rates must be adjusted in order to maintain the trend line. The model adjustment loops will attempt to recover to the trend lines as soon as possible or, if recovery is not feasible, to make the minimum degradation of trends goals.

The Operational System

A second representation of the regional system is closer to the ecological and economic management patterns observed in most U.S. regions today. This procedure suggests that, while there are many system thresholds that must be met, many of the growth and output adjustment choices are not developed in an "optimal" fashion, but reflect existant "policy" and other regional desires and initiatives after satisfying the natural system thresholds. The model then must first determine the area of acceptability of demands and output by interpreting a set of side conditions - resource constraints, demand thresholds, ecosystem minimums, output increase maximums, etc. Given that the outputs for a time frame occur within the area of acceptability meet all demand thresholds, no further adjustment of outputs toward an optimal or growth-maximizing result is made, but, rather, output and export patterns of the past periods are maintained.

This model description and adjustment form remains within our earlier definition of carrying capacity where the area of acceptability is equivalent to the range in which the ecosystem "remains healthy and productive." It also provides a definition of the level to which local desires and mores can prevail - any area-specific pattern is allowed as long as the end result is expected to be within the area of healthy productivity of the ecosystem.

If at anytime, the projections for the ecosystem suggest that the full set of population demands are not met, then the ecosystem resilience is lost and adjustments must be made using the feedback adjustment schemes. These adjustments combine several of the items that are characteristic of the existing regional adjustment mechanisms:

- No overall optimization of the individual component production processes to meet total society goals under normal (healthy) conditions.
- A capability in crisis situations to intensify and unify planning within the public-private processes to meet minimum demand standards.
- Each component of growth and of output individually attempts to adjust productivity to not only meet minimum standards (the society thresholds) but also to increase the resiliency and the stability of system by suboptimization of components in the total system.

It is worth noting that this second management process can be made to approach the first, the regional comprehensive plan process, by raising society minimum demand thresholds toward the realizable goals of the exacting comprehensive production plan.

SUMMARY

In general terms the State of the System Model, described in its simplest form, will allow the user to iterate through time until it is projected that one or another of the system resources will be exhausted or costs of media treatment will become prohibitive. This means that the system can be conceived of as having several independent limits or thresholds any of which will modify its further growth. As one, or all, of the system resources begin to be scarce and relatively expensive, there is a tendency first to skimp on maintenance to a given level and then to curtail affected growth. The indicators of public-private output levels compared to system demands begin to decline consistently and across the board. Unless drastic steps are taken to circumvent the seriousness of the shortage(s), the system may be in terminal decline.

A model of only this descriptive form, however, is of limited use to the policy maker who must make day to day decisions based on little information. Consequently, the State of the System Model is seen to have a number of adjustment loops representing local and partial system reactions, permitting it to serve as a local policy device. In particular a large set of resource adjustment capabilities exist provide a reasonably representation of resource constraints by using economic substitution to effect adjustments.

One application of a model of this type is to test the operating or comprehensive plan of a specific region. The test is of the type which makes the assumption that either plan has represented the appropriate set of recommended changes within the data base, and that the region will make whatever adjustments are necessary to implement the plan. With this design in mind, the model iterates through time constrained by the desired end goals of the local inhabitants. Whenever a specific value (or series of values) is out of phase with the desired plan, the model will adjust itself to refocus the subsequent iterations toward the end goal.

The questions addressed by the model then are whether the region has the capability of arriving at the desired goals of the population given the existing resource problems and the area-specific adjustment processes to manage the region's resources.

SECTION VI

MODEL FORMULATION

GENERAL

This section provides an examination of the principal variables and functional relationships of the State of the System Model. These present the general model structure, the type data required for model operation, and will serve as basis for subsequent research efforts. The relationships are presented in four groups paralleling the four model elements discussed in the Overview (See Figure 5). The groupings are:

- System Inputs - These relationships are associated with the sectors of growth, specifying the total sector change. The inputs include total regional funds and allocation of expenditures to the private and public sector, plus the population size, age distribution and quality of life demands.
- System Outputs - These relationships translate the inputs to an overall demographic and economic description of the region for the year considered.
- State of the System - These relationships are associated with the system limiting factors or demand constraints. They define resource utilization, the quality of the environment and the satisfaction of quality of life demands within the system.
- System Adjustments - The last group of relationships are associated with the long term goals. They provide the necessary adjustments and feedbacks when the state of the system is found to be incompatible with the ultimate goals.

CYCLE CALCULATIONS AND ADJUSTMENTS

In essence, the workings of the SOS Model can be visualized as follows: (See Figure 6)

The particular system under study can be expected (on the basis of known patterns) to grow at a given rate. This growth includes changes in population and goods demands levels plus the funds used by the public and private sectors. During a cycle the desired growth rates would project a production output level. From this set of output levels a set of factors can be checked against the carrying capacity of the system. This carrying capacity can be seen to have two types of limits--those set by the desires of its local inhabitants for output (Quality of Life) and those set by the

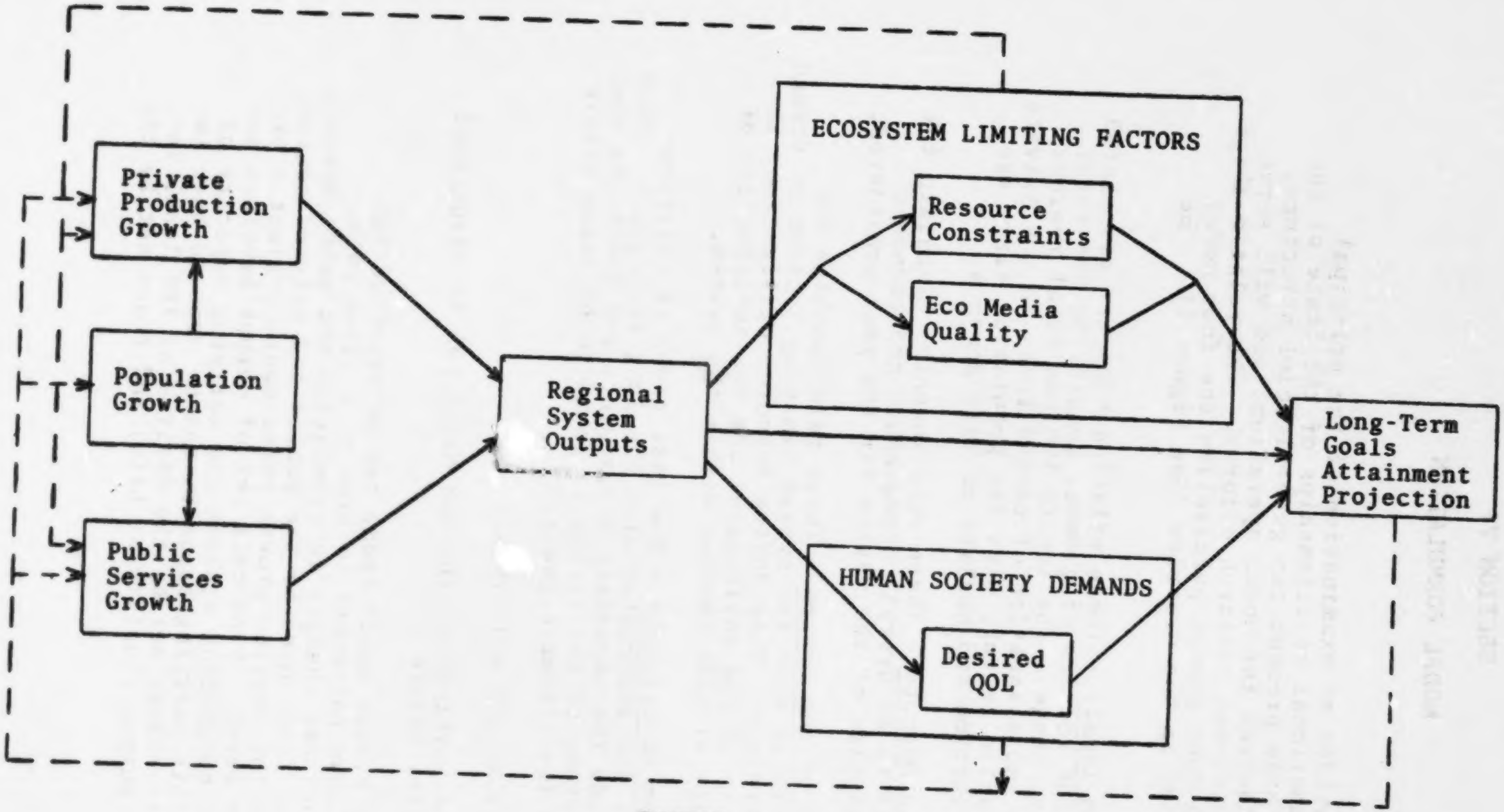

Private Production Growth
Population Growth
Public Services Growth
Regional System Outputs
ECOSYSTEM LIMITING FACTORS
Resource Constraints
Eco Media Quality
HUMAN SOCIETY DEMANDS
Desired QOL
Long-Term Goals Attainment Projection

FIGURE 5

ELEMENTS OF THE MODEL

ecosystem. The human desires tend to be of a short run nature and are changeable through time but not at an instant in time. The ecosystem limiting factor constraints are, of course, more enduring and consist of the availability of natural resources--energy, food, and the like--but include environmental quality.

The model is so conceived that the amounts of resource reserves are set for discrete points in time (normally a yearly increment). Shortages can be due to circumstances which are localized and time dependent, but that do not necessarily reflect a permanent depletion of a resource. On the other hand, because the system reacts to shortages and "brownouts," such occurrences will be handled as system warnings which may produce both short and long run adjustments of resource supply, resource utilization and resource demands.

If the projected output of the system during a particular time period is within the limits set by its carrying capacity and meets the population demands then the model will continue to the next cycle. If the output demands are beyond the system capacity, the projected growth rates will be adjusted and the adjustment cycle repeated until the projected output is within system limits. Throughout this process, the growth of the study system is compared against the stated goals of the inhabitants--the quality of life demand-measures.

The model can also respond to the whim of potential pressure and public fancy. In addition to the "rational" feedbacks of the model itself, it responds to exogenous perturbations. This extra-regional procedure lists the areas of public expenditure, (education, transportation, etc.) and checks to see whether each public area has (1) recently had an infusion of public funds, and (2) is an area where more funds would have a noticeable effect on the Quality of Life. The resultant output from the algorithm is a vector of weights for each public services component as an index of popularity.

SYSTEM INPUTS

Total Production Growth

The model takes its impetus for iteration from yearly growth and development rates. These rates are determined by forces endogenous and exogenous to the system. The closer the regional system is to closure, i.e., the more it represents a worldwide system rather than regional growth expectations, the more the rate of change is endogenously determined. The efficacy with which the growth rates are changed by the feedback loops is the key to the success of the adjustment portions

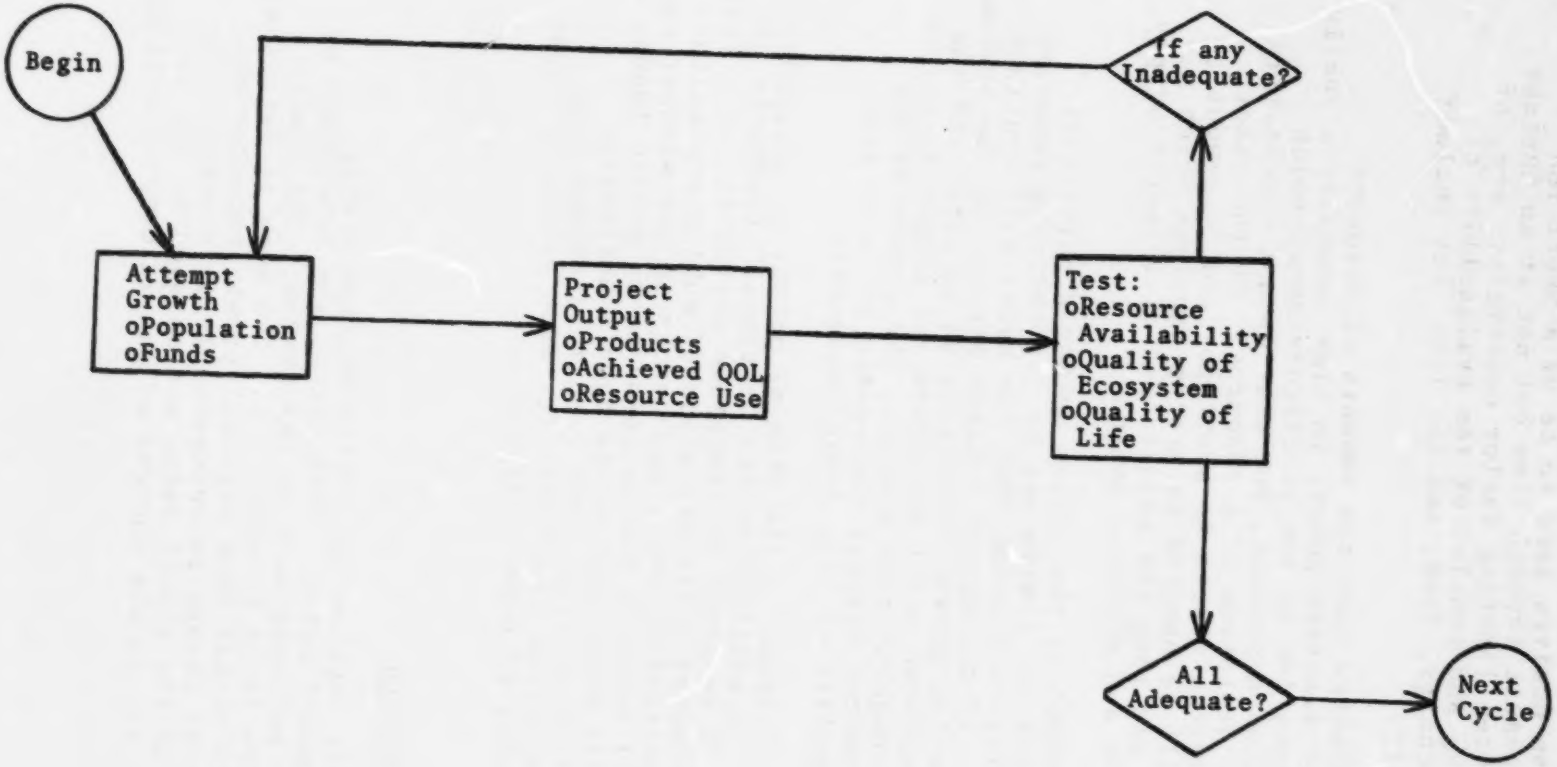

Begin
Attempt Growth
oPopulation
oFunds
Project Output
oProducts
oAchieved QOL
oResource Use
Test:
oResource Availability
oQuality of Ecosystem
oQuality of Life
If any Inadequate?
All Adequate?
Next Cycle

FIGURE 6

ONE CYCLE OF THE MODEL

of the model. However, while the growth rates can change, the total input to the regional system cannot. The input to growth sectors other than population is in terms of funds available for conversion to real goods production plus the maintenance of the physical (developed and undeveloped) elements of the system. The total amount of funds available for a cycle includes two sources - the endogenous funds generated based on consumption of the past period production, and exogenous funds allocated on a non-historical trend, popularity basis. The exogenous funds could represent national to regional transfers and can be negative. The total funds for a region for any time are:

$$TFUND(t) = PRIVFD(t) + PUBLFD(t) + EXOGFD(t)$$

where TFUND(t) is the total funds avialable for use by all production components in the public and private sectors for year t,
PRIVFD(t) are funds generated endogenously by the private sector activities for time t
PUBLFD(t) are the funds generated endogenously for the public sector, and
EXOGFD(t) are the funds transferred to the region from outside sources through importation, subsidies, net taxation transfers, etc., plus the contribution through the popularity vector.

For either the private sector or the public sector, the basic funds for the cycle are equal to the funds generated by each component for the cycle based on its rate of growth. For example the private sector:

$$PRIVFD(t) = \sum_{c \text{ in private}} M\&PFD(c,t-1)*(1+RG(c,t-1))$$

where M&PFD(c,t-1) is the level of funds used by component c in the component's operation last cycle.
RG(c,t-1) is the rate of funds growth provided component c in the last cycle. This rate of growth is a complex function described later in this section and that can undergo further modification in system adjustment processes.

The exogenous funds are made up of two elements, the net exports balance and a cash transfer capability that is not wholly a function of the previous period. This second factor is set to vary based on a probabilistic range about an expected transfer value that is region-specific. For example, for the United States, the value could represent the outflow of aid to other nations funds with a range of variability consistant with the past trends of Congressional appropriations. As a second case, for a region of the United States receiving significant assistance within one of the public component areas, a mean transfer level modified by an annual stochastic variance might be applied.

$$\mathrm{EXOGFD}(t) = \sum_{c} \mathrm{NEXP}(c,t-1) + f(\mathrm{RN},t)*\mathrm{TRNFD}(t)*(1+\mathrm{RGT})$$

where $\mathrm{NEXP}(c,t-1) = (\mathrm{EXP}(c,t-1)-\mathrm{IMP}(c,t-1))*(1+\mathrm{RG}(c,t-1))$

EXP(c,t-1) is the funds received for exports for component c in the last cycle

IMP(c,t-1) is the funds paid out for imports of component c in the last cycle,

f(RN,t) is a weighted random function distribution of transfer fund variability.

TRNFD(c,t-1) is the level of funds transferred into the region last cycle, and

RGT(t-1) is the mean rate of funds growth expected over the long term

This level of total available regional funds sets an upper constraint on inputs to the production sectors and components for the current cycle. The process of allocating funds to production components is done subject to the condition: the funds available to the components must equal to the total regional funds.

The allocation process has two major steps. First, an expected (or median) allocation of funds is provided assuming that the relative growth rates set and adjusted for each component in the past cycle are maintained. Additional increases or reductions of growth rates are introduced as functions of net exogenous-funds-available and the population preference for types of goods or services this cycle. Thus, the general form of the growth of funds for a sector or a component can be represented as:

$$\mathrm{RG}(c,t) = \mathrm{M\&PFD}(c,t-1)*(1+\mathrm{RG}(c,t-1))+\mathrm{EXOGFD}(t)*f(\mathrm{CONPRF}(c,t))$$

where RG(c,t) is the normalized funds growth rate for component c and time t

and f(CONPRF(c,t)) is a function of the regional preference to add or delete funds from component c to adjust to exogenous funding levels in all components. The function is subject to the property that

$$\sum_{c} f(\mathrm{CONPRF}(c,t) = 1$$

and includes components of

f(CONPRF(c,t))= f(Maintenance of capital and media, and exogenous or endogenous preference to invest in component c for this t)

Thus

$$\text{CONPRF}(c,t)) = \text{GROWTH}(\text{MAINT}(c,t) + \text{QOL}(c,t) + \text{RESDEP}(c,t) + \text{PREF}(c,t)).$$

a level of additional directed growth for a combination of factors including capital maintenance (MAINT), environmental maintenance and human desires (QOL), resource depletion (RESDEP), and/or subjective preference of the funds supplier or the ultimate consumer (PREF).

The fund allocation produced by the process above is described below, using the newly generated rates of fund growth for production components, RG(c,t). First, however, a static representation of the production sectors appears useful.

The Production Sectors

The sectors of regional growth, other than regional population and demands, are the production and services components of the private sector and the public sector. The dimension of growth for both sectors, and hence their input to the system, is the level of funds used annually to procure and transform resources into capital and ecosystem maintenance* and sector production outputs (M & P funds).

Due to the need to partition the sectors into more meaningful elements, both the private sector and the public sector are decomposed into components that represent natural regional subdivisions. For the private sector, production components are established; e.g., heavy pollution industry, light polluting industry, commercial goods and services, agriculture, and household-related industries. In the public sector and a national region, typical service components could be education, welfare, safety, defense and administrative services, health, and transportation/communication. In SOS each of these components has related with it a rate of yearly M&P funds growth as defined above.

For static representation of the production elements of the system, the funds expended are:

$$\text{TFUND}(t) = \text{TEXPN}(t) = \text{EXPPUB}(t) + \text{EXPPRI}(t)$$

---

*Capital maintenance here is expansion and maintenance of the facility and equipment of the production element.

All funds available to the region will be expended since over-production is transformed into exports and increased stimuli of population demand.

EXPPUB(t), expenditures in the components of the public sector, and
EXPPRI(t), expenditures in the components of the private sector.

Further decomposition of the expenditures yield that

$$\text{EXPPUB}(t) = \sum_{c \text{ in public}} \text{EXPCOM}(c,t)$$

and

$$\text{EXPPRI}(t) = \sum_{c \text{ in private}} \text{EXPCOM}(c,t)$$

where EXPCOM(c,t) is the expenditures of component c for M & P.

Thus, for any time period, the funds available to the region are balanced by the production expenditures of the region

$$\text{TFUND}(t) = \sum_{c} \text{EXPCOM}(c,t)$$

Expanding the consideration to annual increase or reduction of M & P funds available to the components; for any component, the funds can be calculated from:

$$\text{M\&PFD}(c,t) = \text{M\&PFD}(c,t-1)*(1+\text{RG}(c,t))$$

where RG(c,t) is defined earlier and represents the component investment growth of new regional funds that come into (or out of) the area due to exogenous effects, and due to growth in regional components.

These rates are constructed such that:

$$\text{TFUND}(t) = \sum_{c} \text{M\&PFD}(c,t) = \sum_{c} \text{M\&PFD}(c,t-1)*(1+\text{RG}(c,t))$$

and also that the funds of a sector equal the funds of its components.

As implied in the above formulation, the model is visualized as being responsive to changes in many parameters of the public and private sectors. The model takes direct note of endogenous "rational" changes through the adjustment feedback mechanism discussed later in this section. In addition, the model can also reflect exogenous and endogenous economic and political pressures and public fancy to produce growth in the various components. Generally the latter will be reflected through the preference function within the growth rates.

The Population Sector

Population has been called a passive factor in change by Quinn.(19) He discusses it as being a regional change factor which has great potential, but without corresponding organizational shifts the potential probably will never be realized. Further, population growth as such is not seen as significant in the sense of regional limits until it is related to territory - the larger the physical space in which the population is housed, the less pressure is exerted on the group in the sense of food and living space demands - other things being equal. In fact, the limiting factor of population growth often is not land, food, organization or transportation as described in the society's own domain but may be caused when its growth intrudes on the domain of another society.

For SOS, we shall assume that the necessary organizational structure required to support any level of population will exist when it is required. This means that the expected growth rate of the population of the system will be largely determined from exogenous forces and the regional attainment of societal desires. Changes in population birth and death rates are outside our perview except when the level of satisfaction of demands in a region reaches catastrophically low bounds. The model causes most variation in population growth to occur due to changing area attractiveness; this primary rate-change mechanism is reflected through the net migration rate.

Total Population

Demographers have noted that the changes in population levels, and the composition of the population in terms of its basic characteristics do not change drastically in the short run. The growth of the population each year can best be described by the reasonably constant relationship between the birth and death rates plus the changes in the net migration rates. The migration is postulated to change in accordance with the basic desirability of a specific area. For SOS the basic desirability is a function of employment opportunities and the prevailing level of attainment of the population demands.

The size of the regional population for any year, t, can be calculated by:

$$TPOP(t) = TPOP(t-1)*[1+BRTH(t)+AT(t)*NTMG-DETH(t)]$$

where TPOP(t) is the total population of the region for year t
BRTH(t) is the birth rate for year t
DETH(t) is the death rate for year t
NTMG is the normal net immigration rate for the region
AT(t) is the region attractiveness function for migration during year t, reflecting current system conditions.

Population Characteristics

The demographic structure of the population is of interest in SOS for two reasons. First, the population is grouped into ages. These age groups allow a representation of the resource of labor in terms of level and ability of the regional population to rapidly expand the work-unit supply as a function of production sector demands for the labor resource. Secondly, the population age groups are partitioned to determine the expected consumption rates of the population for types of output; the level of specific demands are affected by the size of the various partitions. Included in this partitioning process are a number of factors that can be corrolated to the regional outputs and represent the present socio-economic level of the society. Typical partition characteristics include:

- length of immaturity/educational time
- mean rates of short-term and long-term infirmity
- ratio of educational units to work units in each age grouping
- death rates by age grouping
- size of worker force, further partitioned as:
    - employed, paid workers
    - unemployed, paid workers
    - workers not in paid status (housewives, volunteers)

The population characteristics are assumed to change directly with the production and services output levels of the private and public sectors. These changes are shifts of population elements from one partition to another, e.g., from unemployed to employed. This is reflected by:

$$RPOP(j,t) = \sum a(j,c)*UTOTO(c,t-1)$$

where RPOP(j,t) is the "relative" population of partition j in year t

UTOTO(c,t-1) is the total output of production component c in year t-1 in real goods
a(j,c) is the factor relating production output to population partitioning.

To obtain actual population values, rather than relative values, the current total population must be applied. Thus:

$$\mathrm{POP}(j,t) = \mathrm{TPOP}(t)*\mathrm{RPOP}(j,t)/\sum_{j} \mathrm{RPOP}(j,t)$$

where POP(j,t) is the size of population partition j in year t.

SYSTEM OUTPUTS

The major inputs used for setting system output are the expenditures by the various production components to produce the output. The input, i.e., the investments discussed earlier, include not only production funds but also maintenance funds. Thus:

$$\mathrm{M\&PFD}(c,t) = \mathrm{TOTO}(c,t)+\mathrm{MAIN}(c,t)$$

where TOTO(c,t) are the funds devoted to production output in year t
MAIN(c,t) are the funds devoted to maintenance in year t

This yields:

$$\mathrm{TOTO}(c,t) = \mathrm{M\&PFD}(c,t) - \mathrm{MAIN}(c,t)$$

Maintenance is considered here as having three major elements and, thus, differs from the usual maintenance expressions that consider only offsetting plant and equipment depreciation. In addition to the capital depreciation offset, the model considers the ecosystem equivalent, the expenditure to restore the environmental media (water and air) to a "clean" state; i.e., the costs of effluent treatment; these ecomedia treatment costs are related to the component output level. The third maintenance element represents the annual expenditure of capital investment to increase the production facilities of the component. Thus:

$$\mathrm{MAIN}(c,t)=\mathrm{TOTO}(c,t)+*(\mathrm{MNDEP}(c,t)+\mathrm{MNEFF}(c,t))$$
$$+(\mathrm{TOTO}(c,t)-\mathrm{TOTO}(c,t-1))*\mathrm{MNCAP}(c,t)$$

where MNDEP(c,t)= depreciation cost per unit of output
MNEFF(c,t)= effluent treatment cost per unit of output
MNCAP(c,t)= capital cost to expand output facilities (allocated over ten years subsequent to the expansion year)

Substituting this into the expression for TOTO(c,t) above yields with simplification:

$$\mathrm{TOTO}(c,t)=\frac{\mathrm{M\&PFD}(c,t)+[\mathrm{TOT}(c,t-1)*\mathrm{MNCAP}(c,t)]}{1+\mathrm{MNDEP}(c,t)+\mathrm{MNEFF}(c,t)+\mathrm{MNCAP}(c,t)}$$

It will be noted in the above expressions that the maintenance components are not constant over time. The depreciation offset costs may vary with time since these costs can be deferred for future times to allow a short-term increase in production funds. Expansion of facilities can change cost over time due to change level of expansion and in construction resource costs. The effluent treatment costs vary over time based on the variation of overall media pollution quantities compared to the system's natural regeneration.

Specifically, for this last consideration:

$$\mathrm{MNEFF}(c,t)=\sum_{m}\mathrm{KMNEFF}(c,m)*f(m,t)$$

where m is an index over the media types (e.g., air and water)
KMNEFF(c,m,) is the cost of totally treating the effluent of one output unit released into media m.
f(m,t) is the fraction of the effluent to media m that must be treated in year t.

The fraction to be treated is determined by first calculating:

$$f'(m,t)=(\mathrm{POLL}(m,t)-\mathrm{CLEAN}(m))/\mathrm{POLL}(m,t)$$

where POLL(m,t)= is the overall pollution level expected if there were no treatment
CLEAN(m) is the level of pollution cleanable by natural processes.

Then:

$$f(m,t)=\mathrm{Max}\left[0,f'(m,t)\right]$$

STATE OF THE SYSTEM

The major measures to describe the state of the system are the levels of available resources and the level and quality of life. Only resource levels will be discussed in detail here. Development of appropriate formulations for quality of life measures is a major part of the future effort for the model. The example model described in the next section illustrates one approach to QOL treatment as non-scalar system demand measures.

Resource Utilization

In addition to the utilization of capital funds and volumes of eco-media within the maintenance element of the expenditures, the outputs of the various growth components use resources in a production-transfer system that is postulated in the model as being directly related to the units of real goods output. Thus for any component, there is operating at any time one or more input/output functions which relate consumption of a combination of resource units to the production of one output unit for the component. For any of the production components, this resource utilization vector has as its components:

$$RU(r,c,t) = \sum_{n} RSIN(r,n,c)*RFTH(n,c,t)$$

where RU(r,c,t) is the number of units of resource r used in year t to produce one output unit by component c

n is an index over a series of possible resource mixes (input/output functions) that can be used by production component c

RSIN(r,n,c) is the number of units of resource r used to produce one output unit by component c, if the nth resource mix is employed

FRTH(n,c,t) is the fraction of component c that mix n in year t.

The use coefficients, RSIN, could also be treated as functions of time. This would allow consideration of the effects of technological developments and their staged implementation on resource usage levels.

The cost for production of a unit of a production component can be developed as:

$$UCST(c,t) = \sum_{r} RCST(r,t)*RU(r,c,t)$$

where RCST(r,t) is the cost to purchase one unit of resource r.

Knowing the output of a component in terms of expenditures (TOTO(c,t)) and the unit production cost, the output of a component in real goods is:

$$UTOTO(c,t) = TOTO(c,t)/UCST(c,t)$$

The total usage of each resource can now be obtained from:

$$TRU(r,t) = \sum_{c} UTOTO(c,t)*RU(r,c,t)$$

Effect of Technology on Resource Utilization

A major consideration for this more general form is the determination of when, and at what cost, technology changes are allowed. The model as conceived admits as future facts that institutional and technological change occurs. To provide for "idea(s) whose time(s) have come" requires an appropriate treatment of the timing and impetus for change.

The procedures provided in the model for incorporation of technological change is driven by the cumulative expenditure of capital toward research and development. The model assumes that R & D expenditures for technological improvements in utilization of natural resources, energy resources, agricultural resources and land density are made at a rate relative to the level a component expends to procure the resource. These R&D investments are cumulated for each resource category and as the threshold of cumulated capital is passed that would cause a technological improvement, the production processes for all components are then adjusted to reflect the input/output transfer improvement due to technology.

Effect of Consumer Preference on Resource Utilization

A second reason for changes in the input/output transfer function is represented by a more gradual trend over the time limits of the model and represents the shift in production output mix demanded by the population to maintain a production level that is considered constant over time. Unlike the change due to technological improvement, this change in consumer education and preference for materials, and its resultant change in types of resources utilized, is considered to be continuous and reasonably linear over a model run of one or two generations. For longer periods of analysis more complex functional forms may be required.

Resource Availability

In general new resource levels are determined by subtracting the total annual usage (TRU) from reserves remaining from the previous year and then adding on the level of replenishment for renewable resources. A key feature of the model's consideration of such resources is that the "available" reserve level is the amount that can be extracted (or otherwise obtained) at a relatively fixed unit cost (see the earlier discussion of resources). Thus resource reserve levels can be increased by improved processing techniques or by accepting a higher unit cost, thus making more ores economically accessible. The latter process is discussed under System Adjustment that follows. Determination of resource availability levels for fixed unit costs are discussed below for each of the various resource categories.

Energy

At any time the total energy stock available to a region is the sum of the amounts of the various energy sources. At the present level of the model no energy utilization types (for example, stationary consumption vis-a-vis moving energy consumers) are made. However, by properly defining levels of substitution of fuel types in the data base, cognisance of consumer types can be made.

The total level is determined as:

$$TSTKE(t) = \sum_{e} STKE1(e,t) + \sum_{f} STKE2(f,t) + HISTKE - NEXPE(t)$$

where RSTKE(t) is the total energy resource for the region in year t.

STKE1(e,t) is the amount of energy that is available for the region by the fuel type e from regional sources, where the fuel source is a non-renewable ore, e.g., a fossil fuel.

STKE2(f,t) is the amount of energy that is available for the region by the energy type of that is renewable but limited in terms of recovery rate from regional sources. These energy types include hydroelectric power, geothermal wells, nuclear fission power plants, solar conversion, etc.

NEXPE(t) is the net export level of energy sources (processed or unprocessed) from the region.

HISTKE is additional energy avialable through a technological breakthrough, e.g., new energy source that requires minor depletion of other regional resources or eco-support media, e.g., magnetic power sources; etc.

Natural Resources

Natural resources, like energy, is normally viewed as a nonrenewable category. However, there are two important hedges in considering the actual stock reserve at any one time. First, for many of the ores, a high level of substitution of other resources within production processes is possible. These substitutions can be caused by technological improvement or simply a trade-off of one element for another, like material. This process in defined here to be substitution within resource strata, and the resources within the natural ores category are assumed to have several strata. Example of strata include trace metals, structural metals, nonmetallic minerals, etc.

A second hedge available to natural resources, but not available to any great degree in the most often used energy sources, is the ability to recycle debris from processed and consumed goods to regain natural ore in the form of salvage. This procedure, tempered by the mobility of the various component products in passing from the system statuses of ore to goods to debris, sets a resource reserve that is once again variable by cost, i.e., the recycling costs that will determine the level of ore salvage from the system debris.

The following equation is used to set the stock levels of each strata:

$$\mathrm{TSTKN}(s,t) = \sum_{n\epsilon s}(\mathrm{EXTR}(n,t)+\mathrm{RECY}(n,t) - \mathrm{NEXPN}(n,t))$$

where TSTKN(s,t) is the level of natural resources in strata s for year t.
EXTR(n,t) is the amount of natural resource of type n extracted in the region
RECY(n,t) is the amount of natural resource n salvaged in the region through recycling.
NEXPN(t) is the net export of natural resource n from the region and the summation is over all resources in strata s.

The mix of extraction to recycling is a function of the relative costs associated with preparation and distribution of each mode. This adjustment is assumed in the example SOS Model to be a continuous process of cost minimization.

Land

Within a given region the total amount of land does not significantly change. While it is possible to create some new acreage from surface water areas or to lose minor amounts of land due to erosion, the relative change in total land form is judged insignificant for consideration at the total stock perspective.

The major considerations with respect to land availability is availability by land use type, and the potential conversion costs between land use types. Thus:

$$TSTKL(t) = \sum_{u} DRTL(u)*STKL(u,t)+RCLM(t)$$

where TSTKL(t) is the total available stock of land.
STKL(u,t) is the stock of type u (e.g. residential, industrial, commercial, agricultural recreational and undeveloped)
DRTL(u) is the expected depreciation rate of land use type u
RCLM(t) is the land under reclamation.

Methods for expanding reserves of a land use category are developed similar to other resource categories. The maximum potential for transformation at various cost levels is defined. If the potential land that can be transformed is added to the existent stock of land, the sum represents the total stock level for a given land use in a region at a given land cost. From these data a resource reserve generation procedure, as used in non-renewable resources, is possible. In this procedure land use succession adjustments is activated for a given land use type as the unused land use reserve reaches a stock depletion warning level. At that time additional reserves for that land use are generated by a minimum cost algorithm. The major difference in the land category procedure from that of ores is that generation of new reserves in one land use category requires their removal from others.

To generate new land of a specific category requires developing a minimum cost transformation from all other land categories. Thus the cost to produce one unit of land stock u is:

$$CSTL(u) = f(TCP,STKL(u'))$$

where T is a matrix of transformation by land use
C is a matrix of indices representing the amount of STKL(u') that is aesthetically acceptable as STKL(u)
P is a matrix of indices representing the amount of STKL(u') that is topographically consistant with STKL(u).

Application of this expression in a cost minimization routine will generate the amount and sources of new land of type u for a given cost.

The matrix of transformation costs (T) is simply a table of coefficients which relates, in the form of a square matrix, an index of the relative costs for transforming a unit of land to any of the defined land uses form any other. In general form, the coefficients employed on these cells can be subject to price and technological change. Taken in conjunction with the topographical and aesthetic matrices which modify availability to reflect physical, legal and cultural constraints, the cost matrix defines the potential maximum for any particular land use in an area at a point in time for a given cost.

Agricultural Resources (Foods and Fibers)

Based on research in the field of resource availability and national needs, specific emphasis should be placed on the agricultural portion of the resource base. Availability of agricultural products to the regional system is given by:

$$\mathrm{TSTKA}(t) = F(\mathrm{DRTL}(u)*\mathrm{STKL}(u,t))+\mathrm{IMPTA}(t)+\mathrm{SEA}(t)$$

where TSTKA(t) is the total available agricultural resource
u is the land use index representing agricultural use.
IMPTA(t) is the net import level for agricultural products.
F( ) is an agricultural production function related to resource costs per agricultural land unit.
SEA(t) is the amount of the resource obtained from the sea.

Capital

Capital is also an important renewable resource used as an intermediate step between raw materials and final consumption This resource is measured by:

$$\mathrm{TSTKK}(t) = \sum_{k} \mathrm{STKK}(k,t-1)*(1+\mathrm{MNTK}(k,t) - \mathrm{DRTK}(k))$$

$$+\sum_{c} (\mathrm{RDK}(c,t) + \mathrm{INVK}(c,t))$$

where TSTKK(t) is the total capital stock in year t
STKK(k,t-1) is the stock of capital type k for the previous year
DRTK(k) is the decay rate of capital type k
MNTK(k,t) is the maintenance rate of capital type k to offset decay
RDK(c,t) is the capital investment in R&D by production component c
INVK(c,t) is the investment in capital goods by production component c

Labor

Labor as a resource is measured in work units. The population partition representing paid workers provides at any time the instantaneous maximum labor supply level (the labor reserve). The labor cost unit is a function of the rate at which this level is utilized at that time--the full labor force employment rate. Additional labor units can be generated as a function of this rate by transferring, in later time periods, work units from the population partitions of-in training or in-unpaid-work-activities.

This resource is measured using:

$$TSTKW(t) = g(POP(j,t-1), EMPR(t-1))$$

where TSTKW(t) is the total labor resource for year t
j is the population partition representing paid workers
EMPR(t-1) is the previous year employment rate
g( ) is a function which adjusts work force size based on an employment rate reference point.

Air

Unlike with other resources, the model is not concerned with the quantity of the air media. Rather, it is the pollution in the air which is of concern. This is determined from:

$$POLL(a,t) = POLL(a,t-1)* \left[\sum_{c} \frac{TOTO(c,t)}{TOTO(c,t-1)} - Ba*KLNA \right]$$

where POLL(a,t) is the air pollution level
KLNA is the percent of total expenditures devoted to perfect air cleanup.
B is a pollution coefficient indicating the efficiency of cleanup.

This value is used in the ecosystem maintenance function discussed earlier under system outputs.

Water

Water, like air is measured in terms of pollution generated. This level is expressed similar to the air formulation:

$$POLL(w,t) = POLL(w,t-1)* \left[\sum_{c} \frac{TOTO(c,t)}{TOTO(c,t-1)} - Bw*KLNW \right]$$

where the parameters are defined similar to their air pollution analogs.

Level and Quality of Life

The major elements of the state of the system are measured in terms of societal perceptions - a set of judgments dealing with various components of material output and quality of life.

Our particular system must be area-specific, plus represent the planning system that would accomplish the adjustments of growth and output to achieve an acceptable quality of life. Hence, only a general formulation of the quality of life measures can be provided here. First, consider each of the two planning systems discussed earlier as they relate to selection of these state of the system indicators.

In the first alternative - achievement of the comprehensive plan goals - the procedure is reasonably straight forward. Each production goal by itself is a specific threshold to be realized. The relative importance assigned the production goals in the plan provides a set of weighting coefficients to determine priorities in establishing excess production tradeoffs, given that total achievement of goals cannot be accomplished. Thus the only requirement in setting of goals is to restate the production component output goals in terms of parameters as expressed in the model algorithms that measure population demands. These parameters will be primarily measures of real growth; e.g., production component outputs as related to total system population demands, indicators in the form of per capita outputs, the rate of total population growth, and size of specific population partitions.

The second alternative is the system that requires achievement of certain minimum values giving a marginally acceptable life state. It involves supplementary measures relating to the resiliency of the production system in remaining above these per capita demand minimums. Each of the collection of demand measures a dissatisfaction threshold. The resiliency of the system provides an ecosystem adjustment capability measured in terms of the relative demand level above the threshold for that demand.

Unlike the first system, where the measures are generated directly from the comprehensive goals, a set of measures must be selected in terms of the area-specific needs and desires of the society in the region. The general forms of these measures will be similar to those of the plan above with the exception that a minimum acceptable demand value rather than maximum achievement goal is set.

Of greater difficulty for both systems is the setting of relative weights to combine the composite set of measures. However, this need not be accomplished as part of the SOS Model. Instead an iterative process can be carried out, which measures the state of the system as a set of criteria and then adjusts M&P fund levels among the production components until all thresholds are met or a suboptimized minimum miss-distance is projected.

An extension of the procedure of setting thresholds of minimum acceptable values is to have the threshold values change based on population expectations. If for any period of time a value of a demand measure remains high as compared to its threshold, experience suggests that the consumer changes his level of want to a level of need. This is equivalent to increasing the threshold to a new set of demand thresholds representing society desires rather than a more basic set of subsistance needs. In a similar vein, if for a period of time, a population must go without a level of goods or services that it desires, a reduction of the consumer preference is likely. To account for this phenomenon, the thresholds of each measure can be automatically set in the SOS Model as a function of simulated historic output trends.

$$\text{TMEAS}(n,t) = f(\text{MEASn}(\tau); \tau = 1,2,\ldots t-1)$$

where TMEAS(n,t) is the threshold value of QOL measure n at t and,

MEASn(τ) is the achieved value of the measure at a previous time $\tau < t$.

SYSTEM ADJUSTMENTS

For any method of measuring the state of the system, if the present state is found unacceptable, a set of adjustments should be effected in SOS to allow future system states to become more acceptable. The adjustments are performed in the following order until the projected trends indicate acceptability:

(1) Short term adjustments:

  (a) short term deferral of capital maintenance for each output component having a deficient output level and/or

  (b) expenditure of net export balances for importation of goods to supplement components that are deficient

(2) Long term adjustments:

  (a) changing input/output production functions to achieve the minimum cost mix for components having deficient output contributing to unacceptable values of demand satisfaction.

  (b) reallocating the total projected M & P funds level within a sector to better balance projected growth rates and needed outputs of deficient production components (The adjustment of RG(c,t-1)).

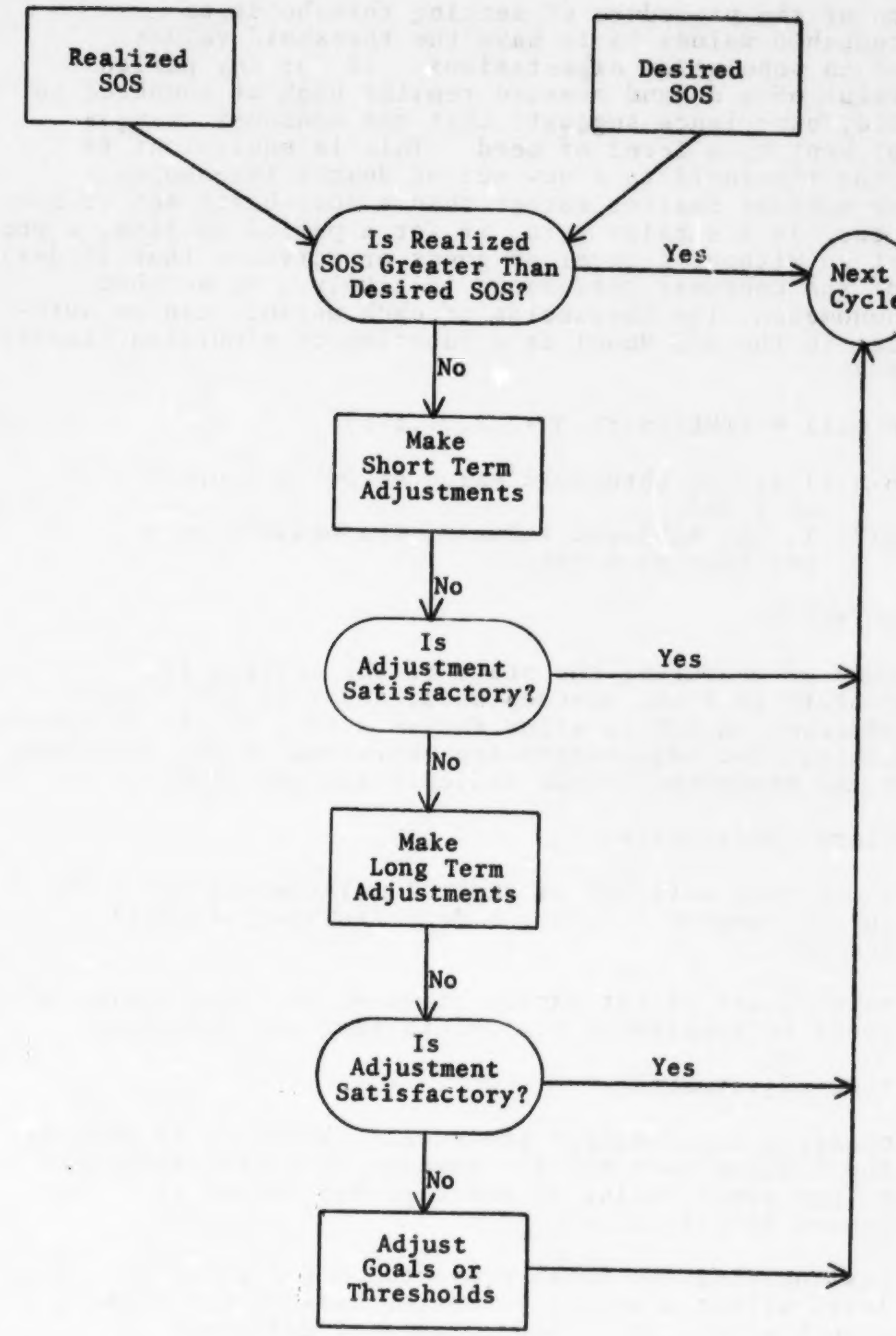

Realized SOS
Desired SOS
Is Realized SOS Greater Than Desired SOS?
Yes
Next Cycle
No
Make Short Term Adjustments
No
Is Adjustment Satisfactory?
Yes
No
Make Long Term Adjustments
No
Is Adjustment Satisfactory?
Yes
No
Adjust Goals or Thresholds

FIGURE 7

SYSTEM ADJUSTMENT PROCEDURE

(c) rescheduling the annual transfer of funds from one sector to the other where deficiencies exist and then repeating procedure (b). This, of course, is used only if all components of one sector are not deliquent and hence can give up growth funds.

(d) adjusting the rates and direction of net migration to reduce per capita consumption needs if significant unemployment exists in the region.

If none of the long term adjustments produce a satisfactory correction of the projected state of the system, one final form of adjustment is made to permit the simulation to continue. In this situation the system goals (for the comprehensive plan analysis simulation) or the level of dissatisfaction thresholds (for the operating system alternative) are modified to lower levels. This will allow a possibility of maintaining the regional growth projections as a stable situation at the cost of a less acceptable level and quality of life.

Figure 7 illustrates the adjustment procedure.

Resource Base Adjustments

Finally, the resource base adjustments are melded into the general carrying capacity model. The following diagram of the adjustment algorithm is illustrative:

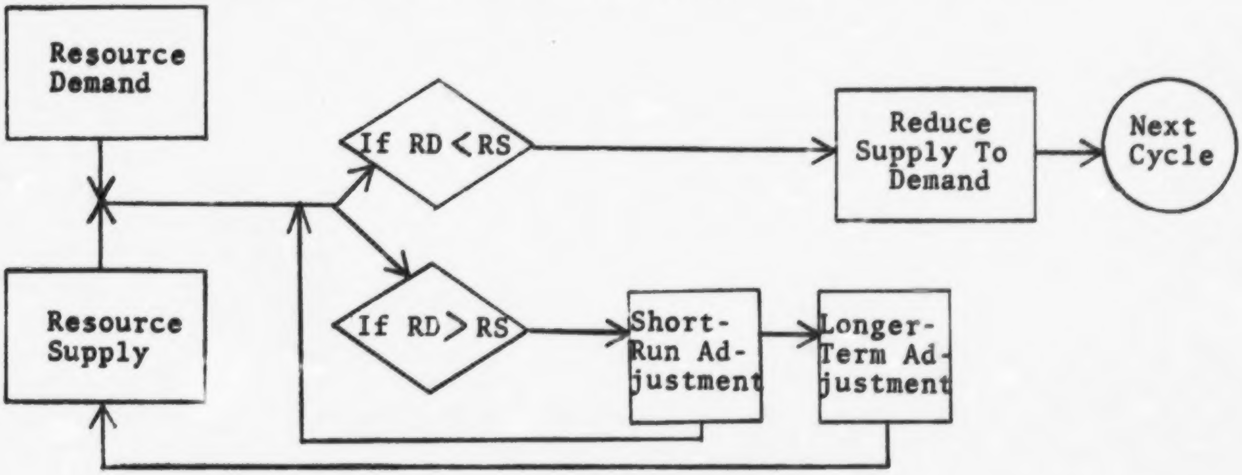


FIGURE 8

Resource Base Adjustment Process

The system reaching a natural limit to its carrying capacity may merely suggest a short run imbalance of the demand and supply of a specific resource. This imbalance can be corrected by changing the rate of extraction and distribution of the resource in question. If, on the other hand, the reaching of a depletion symptom at a particular point in time heralds the beginning of a serious shortage of a particular resource, there are several possible responses:

- The rate of extraction could be increased, because increasing costs increase economically available reserves.
- More supplies could be demanded from other regional systems at higher costs.
- Adjustments may be lower resource use by substituting a more available and lower cost resource mix.

SECTION VII

THE EXAMPLE MODEL (SOS-1)

The State of the System Model provides a new capability to examine a region of national or subnational areas for large countries as a human ecosystem. To represent an ecosystem, the model has a rather complete description of the present state of the regional carrying capacity plus feedback procedures for adjusting growth as a function of the physical needs of the population, technocratic improvement of resource and eco-media utilizaiton, and area-specific societal value judgments and demands. Additionally, it allows for a stable adjustment of processes within the region to account for limitations of resources while maintaining viable historical trends.

MODEL CHARACTERISTICS

As a first step in determining the utility of the SOS Model, an example formulation of the model, SOS-1, has been developed and programmed that has the following major characteristics:

- Three growth sectors are represented: the population of the region with its growth in terms of both size and per capita demands, five production components of the private sector, and five services components of the public sector.
- Up to 15 level and quality of life demand measures can be set. They must be of the form of satisfaction as based on output production per capita for various combinations of output components.
- Up to 20 resources can serve as surrogates for representing the caracteristics of the six resource categories and the two ecosystem media. It is not required that all categories be represented nor need any specific resource be included.
- Any number of substitution formulations for any resource can be set. These substitutions can include up to five resources. Since the resource for which the substitution is to be carried out can be included in the substitution, partial substitution is possible. The substitution algorithm includes the setting of a time length (in years) to fully perform an activated substitution, thus allowing build-up of impact and a capability of overreaction of adjustments.

- At least one, and in most cases, more than one input/output function to represent the mix of resources consumed in the production of each component output can be set. One of these for each component is marked as active at the initiation of the simulation. Also, each production function has an associated time that is required to retool for full application of the function.

- The resource assumptions are as given in the discussion of resources earlier, except no R&D breakthrough or time-dependency for improved resource utilization within an input/output function is considered in the example model. These assumptions are listed at the end of Section 4.

- The methods for measuring the state of the system and for adjusting operating funds levels between production components, substitution of resource allocation and utilization functions, and modification of society demands, are modeled on the second system form (laissaz-faire suboptimization) discussed earlier. This will include consideration of ecosystem concepts that include society demand thresholds and system resiliency plus historical trend maintenance of the division of M&P funds among components given that the minimum demand thresholds are met.

- Model operating characteristics for the test simulation are SOS operation for 25 annual cycles using data for a region similar to the United States with the beginning situation data similar to 1970 statistics.

- Since the model is expected to be operated as a regional model - where the region is national or subnational - the region does not have a high degree of closure. Elements that may be candidates for crossing system boundaries are resource imports, finished goods exports and imports, population migrants, and flow of investment funds. The model must account for each of these and must scale the level of the exogenous activity using model data. Thus the algorithms and data base can be varied to represent trade agreements, the state of the system in other regions, other region resource shortages, import and immigration quotas, etc.

- The present model structure is not at a detailed level but represents its various elements at aggregate levels. Additionally many of the detailed interactions of the components are not simulated or are represented in a much simplified form; e.g., the procedure by which the manufacturing component outputs affect volume of commercial outputs. Many of the elements such as population demands and resource types are depicted by the use of indicators and surrogates. It is anticipated that later model versions will include critical elements and relationships as determined from empirical analysis of early model results.

- A major assumption in the model is the representation of many functions, such as the output coefficients that produce changes in consumer-need partitions, as linear or constant when even the most cursory analysis refutes this assumption when the entire range of possible data values is considered. In this experimental model, general trends in expected ranges of data are to be explored and in these ranges, small compared to the total possible ranges, much of the empirical data suggests that the assigned forms of fit are reasonable. A corollary to these assumptions is the set of assumptions that suggests constancy of many of the relationships over time. Once again the range of the practical analysis is severely limited by this assumption but in the first applications of the model, using total simulation periods of about 25 years, the assumption provides an appropriate level of structural detail.

MODEL STRUCTURE

The model describes the state of the regional system and processes required system adjustments on an annual basis. The general procedure is to operate on the existent data base and the state of the system descriptors as given for the last cycle in order to, first, describe the system for the current cycle and, second, to affect needed short-term (this cycle) and long-term (affecting future cycles only) system adjustments. The general steps required in an SOS cycle are:

DESCRIPTIVE MODULE

- Describe the population,
- Describe the availability of maintenance and operating funds, resource utilization and output levels of the production components,
- Describe the state of the system, in terms of:

resource depletion levels,
quality of ecosystem media,
attainment of social demand goals (measures of level and quality of life),

SYSTEMIC MODULE

- Adjust critical resource usage by substitution of lower cost replacement resource mixes and, if appropriate, expansion of ore extraction and/or recycling facilities in subsequent cycles,
- Adjust short term procurement for additional goods using maintenance or export funds,
- Adjust long-term M&P funds growth trends to meet projected demands for increased output of components and sectors,
- Adjust demand thresholds in future cycles to realizable levels,
- Reset the data base for the next cycle.

The logical flow through these eight steps is provided in Figure 9. Each step of the example model, SOS-1, is discussed in turn below. Additionally, Appendix 2 provides detailed narrative flow charts of the steps of the model, and Appendix 3, the detailed program listings.

THE DESCRIPTIVE MODULE OF A CYCLE

A full description of the regional human ecosystem for a year is developed by the first three steps of the model simulation. The data base used in development of this description is loaded initial information. After the first cycle, nearly all data are modified as part of the last step of the last cycle operation to reset for the next cycle. The description of the system includes:

Population Growth

- Total population
- Total net immigration effect
- Population in each age cohort (4)
- Annual death rate by age cohort
- Cohort populations, each partitioned into six consumption groups

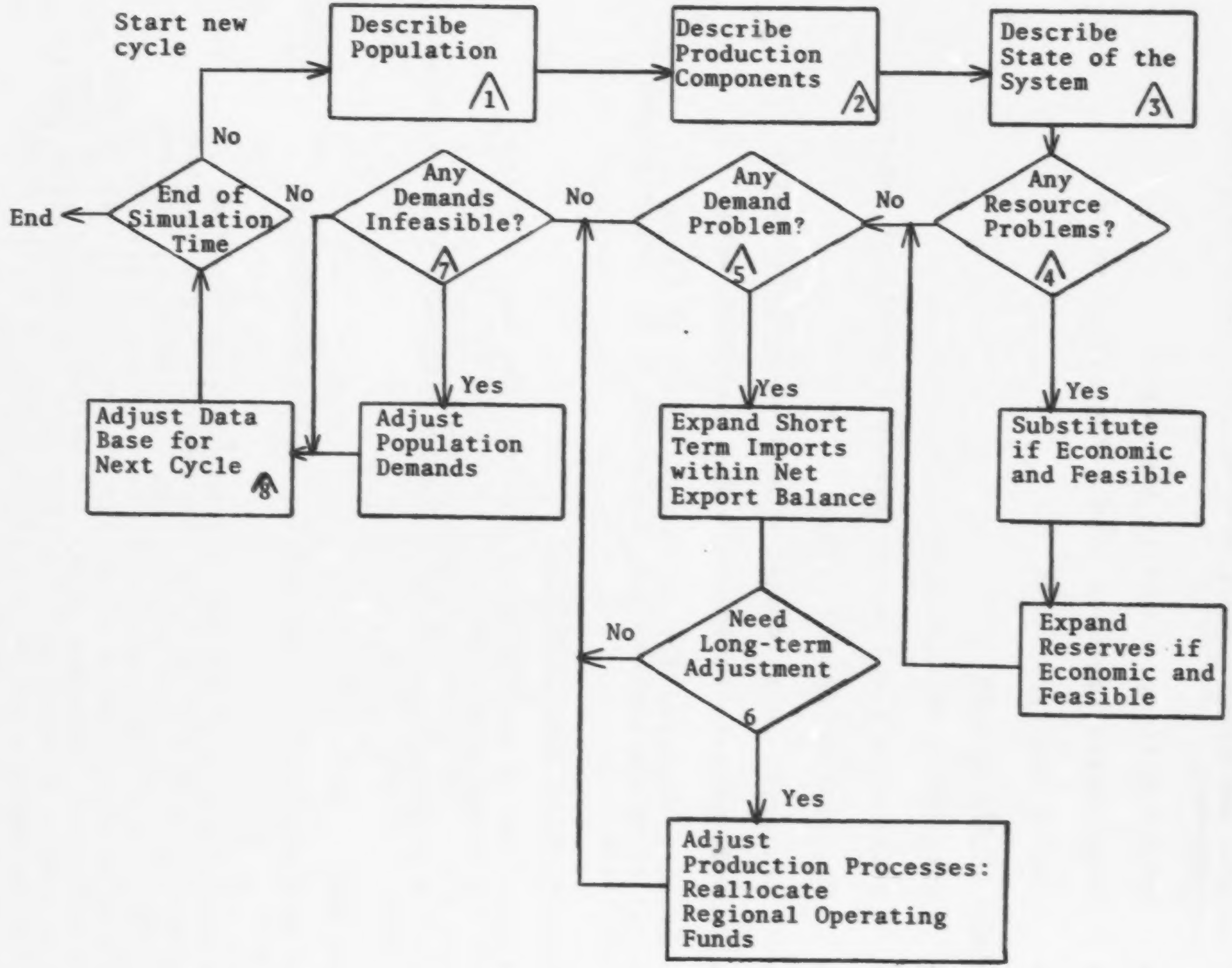

Start new cycle
Describe Population
1
Describe Production Components
2
Describe State of the System
3
End
End of Simulation Time
No
No
Any Demands Infeasible?
7
No
Any Demand Problem?
5
No
Any Resource Problems?
4
Yes
Adjust Data Base for Next Cycle
8
Adjust Population Demands
Yes
Expand Short Term Imports within Net Export Balance
Yes
Substitute if Economic and Feasible
No
Need Long-term Adjustment
6
Expand Reserves if Economic and Feasible
Yes
Adjust Production Processes: Reallocate Regional Operating Funds

FIGURE 9

EXAMPLE MODEL SYSTEM FLOW CHART

Public and Private Sector Components

- Expenditure of funds for generalized maintenance and production processes for each production component
- Output units produced in the region
- Unsatisfied regional demand for output units
- Unit production costs

State of the System

- Attainment of demand satisfaction
- Resilience level above threshold levels of demands
- Unsatisfied demand levels
- Resources in a reserve depletion warning status
- Treatment level required for ecosystem media

The detailed procedures for calculating each of these values and other parameters are discussed in the descriptions of Model Steps 1-3.

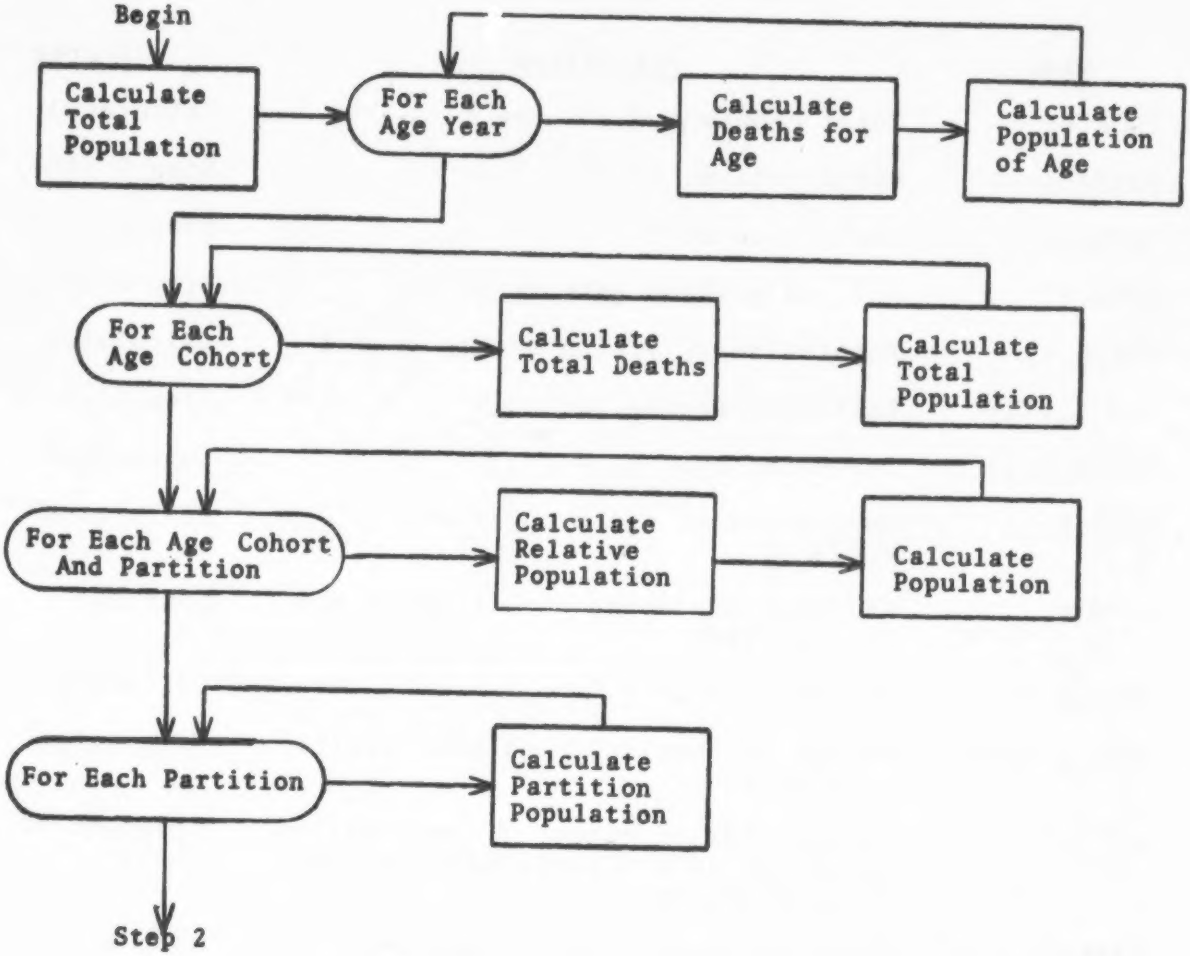
Step 1: Describe the Population

This first step of an SOS cycle provides the full description of the human population of the region for the year of interest (t). The general system flowchart for Step 1 is provided as Figure 10. All data requirements and their sources are listed in Figure 11.

Assumptions

The primary assumptions for developing the demographic data are:

The migrants into (or out of) the region have the same demographic characteristics as the nonmigrating population. Hence, at least as a net effect, the long-standing pattern evidenced in U.S. immigration patterns of early arrival of workers of a family later augmented by the full family is not considered here. However, under the assumption that the time delay in such a process is short and that the population growth rate due to immigration is not large compared to the total population base, this assumption is justified.



Begin
Calculate Total Population
For Each Age Year
Calculate Deaths for Age
Calculate Population of Age
For Each Age Cohort
Calculate Total Deaths
Calculate Total Population
For Each Age Cohort And Partition
Calculate Relative Population
Calculate Population
For Each Partition
Calculate Partition Population
Step 2

FIGURE 10

STEP 1 FLOWCHART

FIGURE 11

STEP 1 PARAMETERS

Name	Definition	Source
TPOP(t)	Total population at time t	Calculated
BRTH(t)	Birth rate at t	Step 8 (t-1)
DETH(t)	Death rate at t	Step 8 (t-1)
NTMG(t)	Net immigration rate at t	Step 8 (t-1)
POP(y,t)	Population in region of age y at t	Calculated
POP(y,t-1)	Last year population of y	Step 1 (t-1)
DTHPT(y,t)	Deaths of y at t	Calculated
GPOP($\bar{y}$,t)	Population of age group y at t; $y_1 \le \bar{y} \le y_2$	Calculated
PDTH(y)	Fraction of deaths occurring in age y population	Constant
GDTH($\bar{y}$,t)	Deaths in $\bar{y}$ at t	Calculated
RPOP(y,k,t)	Change in population of kth partition of $\bar{y}$ at t	Calculated
a(j,k,$\bar{y}$)	Coefficient of output j contribution to change in kth partition size for $\bar{y}$ age grouping	Constant(10,6,4) Matrix
OUTPT(j,t-1)	Units of production of component j last year	Step 2 (t-1)
POP($\bar{y}$,k,t)	Total population of $\bar{y}$ in k at t	Calculated
POP($\bar{y}$,k,t-1)	Total population of $\bar{y}$ in k last year	Step 1 (t-1)
POP(k,t)	Total population in k at t	Calculated

The distribution of death rates among age cohort is assumed to be proportional to the relative population of the group. Hence, throughout the period of simulation a constant death rate for an age cohort can be set.

Change in the size of the six consumption partitions of each age cohorts has been related directly to only the annual output levels of private and public components. While this indicates no explicit direct tie to the quality of life measures of the system capability to meet population demands, defined in Step 3 following, these are also related to the same component outputs, usually on a per capita basis. Thus, the reaction of population partition sizes do reflect the system reaction to level of attainment of quality of life demand thresholds since the reactions have the same independent variables.

Algorithms

The total population within the system for the current year, t, is last year's population plus its increases due to the birthrate and net migration rate minus the loss due to the annual death rate.

$$\mathrm{TPOP}(t)=\mathrm{TPOP}(t-1)*[1+\mathrm{BRTH}(t)+\mathrm{NTMG}(t)-\mathrm{DETH}(t)] \tag{1}$$

All rates can be adjusted due to the present capability of the system outputs to meet the population demands; these adjustments are performed in Step 8 of the previous cycle.

The next calculations develop for each age-year of the population, the total deaths and the age-year populations. An age-year represents for i=1,2,...,64 all population at an age in the range (i-1,i) and for i=65 (i-1, greatest age). The death population is:

$$\mathrm{DTHPT}(y,t)=\mathrm{POP}(y-1,t-1)*\mathrm{DETH}(t)*\mathrm{PDTH}(y) \tag{2}$$

$$\text{for } y=1,2,\ldots,64$$

$$\mathrm{DTHPT}(<64,t)=[\mathrm{POP}(64,t-1)+\mathrm{POP}(<64,t-1)]*\mathrm{DETH}(t)*\mathrm{PDTH}(<64)$$

The living age-year population at t is:

$$\mathrm{POP}(0,t)=\mathrm{TPOP}(t-1)[1+\mathrm{NTMG}(t)]*\mathrm{BRTH}(t) \tag{3}$$

$$\mathrm{POP}(y,t)=\mathrm{POP}(y-1,t-1)*[1+\mathrm{NTMG}(t)]-\mathrm{DTHPT}(y,t)$$

$$\text{for } y=1,2,3,\ldots,64$$

$$\mathrm{POP}(<64,t)=[\mathrm{POP}(<64,t-1)+\mathrm{POP}(64,t-1)]*[1+\mathrm{NTMG}(t)]$$

$$-\mathrm{DTHPT}(<64,t)$$

For the model use in other procedures, most population data is in terms of four age-groups. The age groups, $\bar{y}$, used in the SOS-1 Model are:

$\bar{y}$	age-years
1	1-17
2	18-24
3	25-64
4	64

The cohort annual death rates and living cohort populations are simply summations over the included age years.

$$(4)\quad \mathrm{GDTH}(\bar{y},t)=\sum_{y_1}^{y_2} \mathrm{DTHPT}(y,t)$$

where $\bar{y}=[y_1, y_2]$

$$(5)\quad \mathrm{GPOP}(\bar{y},t)=\sum_{y_1}^{y_2} \mathrm{POP}(y,t)$$

As a final set of calculations of Step 1 the cohort populations, GPOP(y,t) are divided into 6 partitions. These partitions serve two roles in other Steps of the model. First the resource of work units of paid workers and the potential to expand the work unit size is represented by setting the numbers of population in each cohort that are workers in training, paid workers and unpaid workers. Second, the six partitions can be used to represent differing demand levels for the public and private sector output units.

The changes in distribution of cohort population among the partitions are based on weighted linear combinations of the production component outputs of the past period. The relative (or unnormalized) distribution within cohort among the partitions are:

$$(6)\quad \mathrm{RPOP}(\bar{y},k,t)=\sum_{j} a(j,k,\bar{y})*\mathrm{OUTPT}(j,t-1)$$

where k is the partition index k-1,2,...,6 and j is the production component index

The actual population of a partition in cohort is:

$$(7)\quad POP(\bar{y},k,t)=POP(\bar{y},t)*[RPOP(\bar{y},k,t)/\sum_{k} RPOP(\bar{y},k,t)]$$

Finally the total population within a partition is the sum of the partition population over all cohorts.

$$(8)\quad POP(k,t) = \sum_{y} POP(\bar{y},k,t)$$

Population Description Outputs

The output of each annual cycle of Steps 1, 2 and 3 can be suppressed at the submission of a computer run by setting the program print option parameter, NPRNT1=2.0 (see Appendix 4). If the data output is not suppressed, for each cycle the demographic output table as formatted in Figure 12 will be printed.

Additionally, at the end of the simulation, population summary data appears in two table/graph sets. In the Summary Set, a ratio of the system's total population, normalized to the initial total population (TPOP(0)), is provided as one of the nine summary statistics as a yearly tabulation. In the second set, Population, is provided for each year, the total population, and the age-group population as a ratio of TPOP(0).

Step 2: Describe the Production Components

Based on the projected level of funds available for the maintenance and production functions of the components each year and the present procurement costs associated with resources, determine:

- Maintenance costs for each component
- Total resource and labor unit costs for each component
- Units of output for each component
- Present (beginning and ending) reserve levels and unit costs associated with the system resources
- Resource recycling levels, and
- Occurrance of stock depletion warning levels.

The general system flowchart for the Step is given in Figure 13 and all data required by the Step are in Figure 14.

```
                                 ** REGICNAL POPULATICN **

AGE GROUP     POPULATION      ECUCATION    INSTITUTION     PRESCHOOL      NON-WORKER    PAID WORKER  UNPAID WORKER

  TCTAL       21C811.375
   <18         68468.812      48666.809        455.099     19229.645         117.276            0.0            0.0
   18-24       26258.555       8296.637        238.529           0.0         487.753      14437.668       2797.988
   25-65       93443.687            0.0        596.854           0.0         778.746      64857.703      27210.387
   >65         22114.980            0.0       1278.106           0.0       20836.871            0.0            0.0
```

FIGURE 12

REGIONAL POPULATION FOR A CYCLE

FIGURE 13

STEP 2 GENERAL FLOWCHART

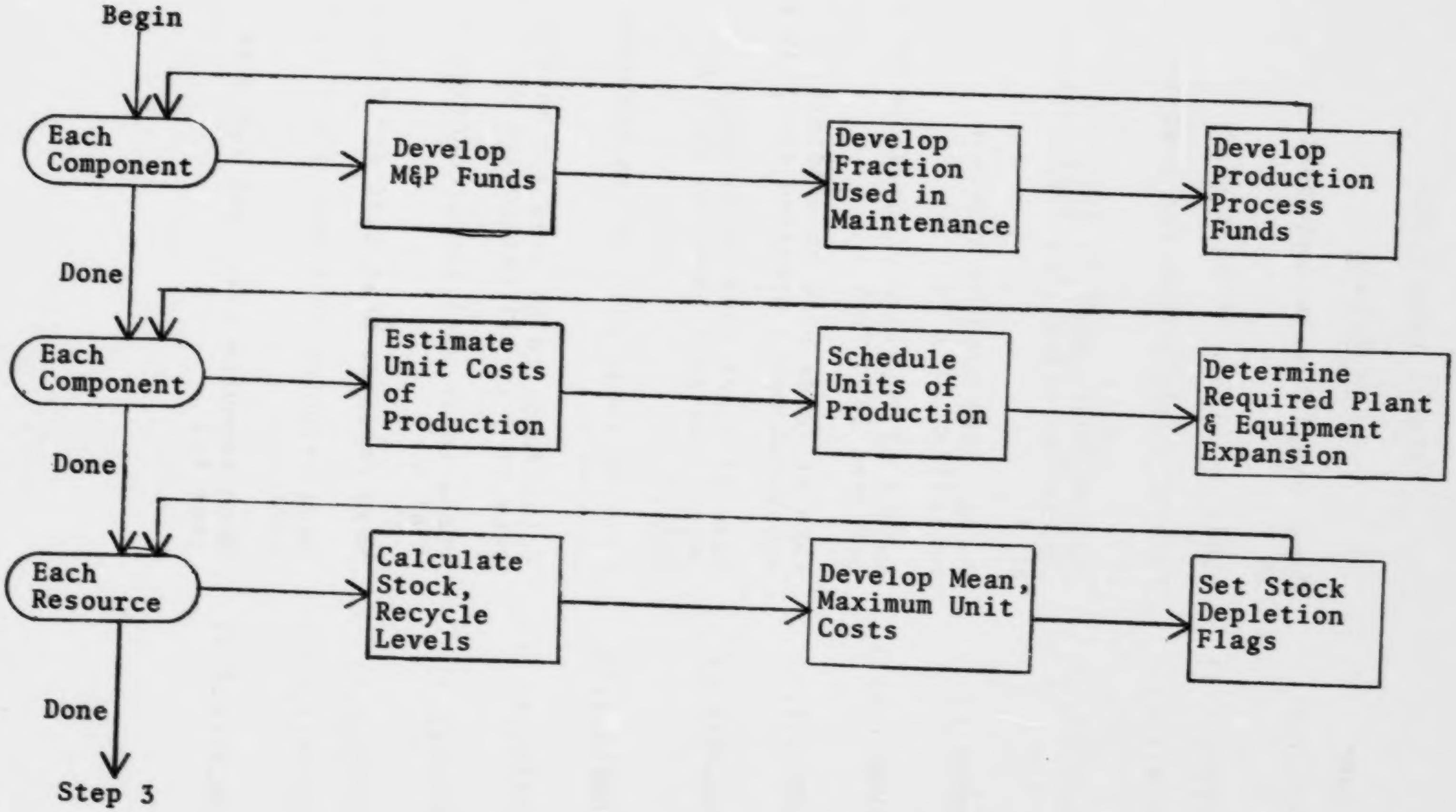

Begin
Each Component
Develop M&P Funds
Develop Fraction Used in Maintenance
Develop Production Process Funds
Done
Each Component
Estimate Unit Costs of Production
Schedule Units of Production
Determine Required Plant & Equipment Expansion
Done
Each Resource
Calculate Stock, Recycle Levels
Develop Mean, Maximum Unit Costs
Set Stock Depletion Flags
Done
Step 3

FIGURE 14

STEP 2 PARAMETERS

Name	Definition	Source
M&PFD(j,t)	Funds available to component j at t	Calculated
M&PFD(j,t-1)	Funds available to last year	Step 2, t-1
RGROW(j,t)	Rate of funds growth for j at t	Step 6, previous t
RMNFAC(j,t)	Rate of funds used to maintain facilities offsetting depreciation at t	Calculated
RMNNOR(j)	Normal rate used to maintain facilities of j	Constant
DEFMN(j,t-1)	Amount of facility maintenance of j deferred last year	Step 5, t-1
RMNECO(j,t)	Rate of funds used to maintain ecosystem media prorated for j at t	Step 8, t-1
REXCAP(j,t)	Rate of funds used to increase facilities at t based on past j output	Step 8, t-1
REMAIN(j,t)	Rate of funds used for maintenance of j at t	Calculated
MNFD(j,t)	Total funds to be used for maintenance of j in all categories at t	Calculated
PRDFD(j,t)	Funds to be used for production of j at t	Calculated
RUCST(r,t)	Mean resource unit cost for r at t	Calculated
RUCST(r,t-1)	Mean resource unit cost for r last year	Step 2, t-1
RUCST(r,t-2)	Mean resource unit cost for r in year t-2	Step 2, t-2

FIGURE 14 (CONT)

STEP 2 PARAMETERS

Name	Definition	Source
UTIL(r,j,t)	Required amount of resources to output one unit of j using current production formula(s) mix	Step 8, t-1
UOCST(j,t)	Unnormalized unit cost to produce output of j at t	Calculated
KFACT(j)	Unit cost normalizing factor for j	Step 2, Cycle 1
OSCT(j,t)	Unit cost to produce output of component j at t (normalized)	Calculated
ROUTPT(j,t)	Rate of increased output over past cycle at t	Calculated
OUTPT(j,t-1)	Number of units produced by j, last year	Step 2&5, t-1
RESOUR(r,j,t)	Units of resource r used by j at t	Calculated
RESOR(r,t)	Units of resource r used all j at t	Calculated
STKDEP(r,t)	Fraction of resource r reserves expended at start of cycle t	Step 8, t-1
ESTCK(k,r,t)	Fraction of resource r reserve expended at end of t	Calculated
REREC(r,t)	Ratio of resource recycled to extracted at t	Calculated
PILE(r,t)	Amount of total reserve available at unit cost for t prior to depletion	Step 8, previous t
STKEX(r,t)	Amount of resource extracted at t	Calculated
STKRE(r,t)	Amount of resource recycled at t	Calculated
MRCST(r,t)	Maximum unit cost of resource at t	Calculated
MRCST(r,t-1)	Maximum unit cost of resource, last year	Calculated

FIGURE 14 (CONT)

STEP 2 PARAMETERS

Name	Definition	Source
ECST(r,t)	Mean unit cost of r at t	Calculated
MECSTR(r,t)	Maximum unit procurement cost of r at t	Calculated
ECSTR(r,t)	Mean unit procurement cost of r at t	Calculated
COMEXP(j,t)	Cost of facilities expansion in t for component j	Calculated
FLAG(r,t)	Existance of depletion warning this year for resource r	Calculated
VFLG(k,r)	Depletion levels of existant stockpile on which warnings are set	Constant
MOUTPT(j,t)	Maximum output level of j prior to t	Step 2, previous t
FCOUTU(j,t)	Fraction of existant facilities of j in production at t	Calculated

Assumptions

The general resource functions listed at the end of the fourth section of this paper are applied here in the development of data and cost functions for the eight resource categories.

Maintenance to offset depreciation of facilities and the ecosystem are assumed to be linear functions of the operating levels of the various components as produced in the last cycle.

Capital expansion costs are set based on whether the output level of a component is greater than the output of any previous cycle. If so, an expansion cost as a linear function of the difference in outputs is set and spread evenly over ten years of annual payment. This cost is included in the maintenance portion of M&P funds.

Many of the data approximations are performed here as simple interpolations, reducing computer running time. When more exacting algorithms and data are introduced, refinement of estimating procedures with SOS using iterative procedures should be included.

Algorithms

Many of the calculations of this step are performed multiply. For example a component calculation must be repeated for all ten components; a resource calculation for each of the 20 resources. Throughout this and subsequent steps the index j will be used for the 10 components of the production sectors and index r for resources.

The first calculations of Step 2 generate the new level of M&P funds available in time period t, and then determine the level spent on the maintenance component with the residue available as the production funds. Note that the maintenance is the generalized form discussed in the general model formulation (Section 6), and includes capital expansion funds; capital maintenance, current and deferred; and ecosystem effluent treatment costs.

Available operating funds for component j are:

(9)   M&PFD(j,t)=M&PFD(j,t-1)*[1+RGROW(j)]; j=1,2,...,10

The funds used for maintenance of existing facilities, as a fraction of total available funds are the sum of this years value and funds needed due to deferred maintenance last year.

(10) $RMNFAC(j,t)=RMNNOR(j)+[DEFMN(j,t-1)/M\&PFD(j,t)]$

The total funds for all forms of ecosystem maintenance, as a fraction of M&P funds are the sum of fractions needed for maintenance, ecomedia treatment, and facility expansion.

(11) $RMAIN(j,t)=RMNFAC(j,t)+RMNECO(j,t)+REXCAP(j,t)$

(12) $MNFD(j,t)=M\&PFD(j,t)*RMAIN(j,t);\ j=1,2,\ldots,10$

The funds available for production costs are the total funds reduced by the maintenance funds.

(13) $PRDFD(j,t)=M\&PFD(j,t)/(1+RMAIN(j,t))\ j=1,2,\ldots,10$

The second major set of calculations of Step 2 provides the setting of an estimated unit cost for producing one output unit of component j and then schedules the total level of output units that will be produced by the system. Prior to these calculations the estimated mean procurement cost to components for each of the 20 resources must be made. The estimate is based on the assumption that the cost per resource unit will maintain the same rate of increase noted in the previous year.

(14) $RUCST(r,t)=2*RUCST(r,t-1)-RUCST(r,t-2)$

for all r.

For each component there is a current mix of resources that are required to produce one unit of output, the set [UTIL(r,j,t)]. An unnormallized unit cost to produce one level of output can be produced by:

$$UOCST(j,t)=\sum_{r} UTIL(r,j,t)*RUCST(r,t)$$

This volume is then normalized (or scaled) using a normalizing factor developed by SOS-1 in Step 2 of the first cycle of each simulation. In order to be able to compare growth among the several components that produce diverse goods and services, a common form of output is required that gives relative output volume rather than a strict listing of products. For this reason the normallizing procedure is based on the model scaling of all output levels of the first cycle to be 1,000 units (see the data discussion of the next section). Under that condition the normalizing factor, KFACT(j), is developed as:

$$KFACT(j)=PRDFD(j,1)/1000.*UOCST(j,1)$$

Then the normalized output unit cost, OCST(j,t), of any cycle is:

(15) OCST(j,t)=KFACT(j)*UOCST(j,t) j=1,2,...,10

This use of a normalizing cost factor deserves further explanation in order to explicitly state its assumptions. The production formula for component j, [UTIL(r,j,r)] includes only 20 surrogates of resources. It is decidedly easier to calculate present day resource costs in terms of the known present day costs of the resource surrogates than to determine in detail all resources and their costs for, say the commercial component and then assign each resource to a surrogate category that has a single mean cost set. Therefore, under the assumption that the set of resource surrogates are appropriate and the second assumption that the mix of surrogates in the production equation is generally balanced, the alternate procedure of developing an unnormalized cost is used. This cost, if the resources are properly balanced, should have its component costs in approximately the ratios that are observed in the base year data. Then the normalization maintains this ratio and allows the scaling of the diverse set of component outputs to an output volume that is easy to interpret as trends in later cycles.

The output scheduled for each component, scaled to the original value of 1,000, is:

(16) OUTPT(j,t)=PRDFD(j,t)/OCST(j,t)

Based on the scheduled output levels it is now possible to calculate the resources utilization requirements of the system, including the labor force, land use, and media treatment requirements. First the resource requirements for each production component are calculated and then these are summed to give the system's total requirements.

For each (j,r) combination; j=1,2,...,10; r=1,2,3,...,20;

(17) RESOR(r,j,t)=OUTPT(j,t)*UTIL(r,j,t)

and for each resource r;

(18) $\text{RESOR}(r,t)=\sum_{j}\text{RESOR}(r,j,t).$

The status of resource data at the end of the cycle, and for mean values, can be calculated. Data of interest are unit procurement costs, end of period stock status, stocks extracted, stocks obtained by recycling, and cost to extract a unit plus recycle the associated ratio of stocks from production debris. All of these calculations are based on the assumptions used in determining stock levels and costs provided at the end of Section 4 plus the simplifying assumption on calculations that simple interpolation procedures can be used, rather than iterating for more exact solutions. Each of the following calculations are done for each resource. The information produced does not affect the scheduled production levels that are set above but are used for display of resources availability and costs for the year and in the resource adjustment calculations that appear in Step 4.

The end of cycle stock depletion level is the fraction of the total stockpile that was originally available to the system at the present unit extraction cost. This is not necessarily the stockpile available at $t=0$. It is the fraction that was depleted at the beginning of the cycle (and end of last cycle) plus the fraction of stock that is extracted and used during the present cycle.

(19) $$ESTCK(r,t)=STKDEP(r,t)+RESOR(r,t)/[PILE(r,t)*[1+REREC(r,t-1)]]$$

The actual quantities of stock that are extracted and are recycled are calculated as:

(20) $$STKEX(r,t)=PILE(r,t)*[ESTCK(r,t)-STKDEP(r,t)]$$

(21) $$STKRE=RESOR(r,t)-STKEX(r,t)$$

The recycling rate associated with the end of cycle stock depletion levels for this cycle, and used in the next cycle calculations is a function of the ESTCK value since the unit costs are directly associated with ESTCK.

(22) $$REREC(r,t)=K4(r)+K5(r)*ESTCK(r,t)^2$$

where K4(r) and K5(r) are constants defined in the next section.

The maximum unit extraction costs are also a function of the value of ESTCK. In order that the system not consume resource stocks that are not available, the regulatory mechanism is set within this function by causing rapidly escalating costs as the depletion of the existant stockpile is approached. Two escalating factors are included: one is a permanent unit cost increase while the second, used only if overusage of resources appears imminent, produces a temporary severe escalation of the unit costs. The general unit costs equation to represent the end of cycle or maximum unit costs is:

(23) $\mathrm{MRCST}(r,t)=[\mathrm{K1}(r)+[\mathrm{K2}(r)*\mathrm{ESTCK}(r,t)\mathrm{K3}(r)]]*\mathrm{TEMP}(r,t)$

where TEMP(r,t), the temporary escalatory factor is

(24) $\mathrm{TEMP}(r,t)=\mathrm{Max}[1.0,[[1.+\mathrm{K6}(r)]/[1.-\mathrm{ESTCK}(r,t)]]^{\mathrm{K7}(r)}]$

In the experimental model data base K6(r) = .90 except for labor where K6(r) = .92, and K7(r) = 3 for nonrenewable resources, K7(r) = 1 for renewable resources and K7(r) = 2 for labor.

The mean unit extraction cost is interpolated between the maximum values for last cycle and this cycle.

(25) $\mathrm{ECST}(r,t)=.5[\mathrm{MRCST}(r,t)+\mathrm{MRCST}(r,t-1)]$

Since it is assumed that the extraction unit costs include the cost for producing the associated recycled ores, the unit procurement costs are set as:

(26) $\mathrm{MECSTR}(r,t)=\mathrm{MRCST}(r,t)/[1+\mathrm{REREC}(r,t)]$

(27) $\mathrm{ECSTR}(r,t)=\mathrm{ECST}(r,t)/[1+\mathrm{REREC}(r,t)]$

The final calculation that is general to all resource data is determination as to whether the stock depletion level has reached a point where it is considered critical. Four critical points can be set for a test of the present range of depletion for each resource; if the value was passed during the current cycle, a critical depletion flag is set to signal the need in Step 4 to consider available, economic adjustments of stock availability and utilization. The form of the test is:

(28) If $\mathrm{ESTCK}(r,t-1)<\mathrm{VFLG}(k,r)\le\mathrm{ESTCK}(r,t)$ then

$\mathrm{FLAG}(r,t)=1.0$ for $i=1,2,3,$ or 4

Also if $\mathrm{ESTCK}(r,t)\le .985$

$\mathrm{FLAG}(r,t)=1.0$

Otherwise, $\mathrm{FLAG}(r,t)=0.0$

In addition to the general calculation for all resources, some special calculations are performed in the Step for specific resource categories. These calculations include the tying of agricultural product output levels and the end of period stockpiles of foods and fibers to the same levels, adjustment of renewable stocks, after testing for depletion levels of each, to the original values and calculation of funds required for capital expansion plus determination of level of existant facilities that are presently in production.

For agricultural levels it is assumed that the initial output levels of 1,000 produces an annual 100% replacement of initial food stocks and an annual 5% replacement of fiber stocks. Thus, for all cycles a third term is subtracted from equation (19) for these two resources equal to:

$$\mathrm{K8}(r)*\mathrm{OUTPT}(j,t)$$

where r is food or fiber
and j is the agricultural production component

For all renewable resources (e.g. land, labor, electricity) after the stock depletion tests are made as shown in equation (28), the stockpile size is returned to its original value as of the start of the cycle.

The usage of existant production facilities and the need to expand these facilities is the last set of calculation in Step 2. Throughout the simulation, for each production component, the maximum output in any previous cycle is maintained (MOUTPT(j,t)). The first calculation provides a test of the amount of facilities that are used in this cycle:

(29) $\mathrm{FCOUTU}(j,t)=\mathrm{OUTPT}(j,t)/\mathrm{MOUTPT}(j,t)$

If FCOUTU(j,t) is greater than 1.0 the facilities must be expanded to account for the excess. The cost of expansion is:

(30) $\mathrm{COMEXP}(j,t)=\mathrm{OUTPT}(j,t)*[\mathrm{FCOUTU}(j,t)-1]*\mathrm{EXCST}(j,t)$

where EXCST(j,t) is the expansion cost for production of one unit of component output.

These costs are spread over a 10 year period and are added to other costs assigned these years from past expansion. Hence for all t'=t+i; i=i,2,2,...,10

(31) $\mathrm{REXCAP}(j,t')=\mathrm{REXCAP}(j,t')+0.1*\mathrm{COMEXP}(j,t)$

Production Component Description Outputs

If the cyclic data output for Steps 1, 2, and 3 are not suppressed, component data and resource data are printed as formatted in Figures 15 and 16. In the tabulation a component or a resource number is associated with the element's name; in later tables or diagnostic messages only the number is printed. For resources having no name, no data is being processed; these numbers are available for later expansion of SOS-1 data bases, e.g. addition of a fourth energy resource category. Units for all data entries are discussed in the next section. These values normally follow the following scaling rules:

```
                              ** COMPONENT OPERATING DATA  **

   COMPONENT            OPERATING     MAINT.    PRODUCTION      OUTPUT     CAPITAL    ANNUAL %
NO.      NAME          FUNDS(1000$)   COST(%)   FUNDS(1000$)               % USED     EXPANSION
1       EDUCATION        98787.437      3.99      94996.687     1353.1      100.0        4.41
2  TRANSPORTATION        17691.711     10.00      16083.980      999.4       97.2        0.40
3          HEALTH        48408.422      8.74      44518.348     1435.7      100.0        5.30
4   DEFENSE&OTHER       152810.125      4.00     146926.312     1140.6      100.0        1.90
5         WELFARE       262219.687      5.76     247937.250     1388.4      100.0        4.80
6   HVY POLLUTING       280528.562      6.72     262860.875     1097.2      100.0        1.33
7   LGT POLLUTING       176729.750      8.51     162863.312     1091.6      100.0        1.26
8      COMMERCIAL        50773.926      8.28      46893.020      939.8       92.3        0.26
9     AGRICULTURE        86800.562      2.00      85098.625      917.4       91.7        0.0
10     HOME & REC       381313.875      6.44     358232.500     1192.8      100.0        2.55
```

FIGURE 15

REGIONAL PRODUCTION COMPONENT DATA FOR A CYCLE

```
                    ** RESOURCE UTILIZATION DATA **
     RESOURCE
NO.      NAME          UTILIZATION             REMAINING   RECYCLE   THIS CYCLE
                     USED IN YEAR   % USED     STOCKPILE    RATIO     UNIT COST
 1          IRON        213.78      14.96      8504.23      0.0     0.00004995
 2        COPPER        274.16      28.75     10342.94      0.06    0.00006810
 3     LEAD,ZINC        354.26      31.16      9166.43      0.08    0.00001247
 4       MERCURY        479.51      71.31      3586.22      0.51    0.00000110
 5        SILVER        250.15      79.26      2281.63      0.38    0.00000427
 6   TRACE METAL        268.72      13.03      8696.66      0.0     0.00000790
 7          COAL         55.65      53.56      4644.13      0.0     0.00091071
 8           OIL        541.60      35.03      6497.30      0.0     0.00013504
 9   ELECTRICITY       5714.14      57.14      4285.86      0.0     0.00005385
10                        0.0        0.00         0.0       0.0     0.0
11        LUMBER        568.57       0.00      9999.99      0.00    0.00016700
12          FOOD       9101.82       0.00      9999.99      0.0     0.00033000
13                        0.0        0.0      10000.00      0.0     0.0
14    URBAN LAND       7571.52      75.72      2428.46      0.0     0.00001552
15 SUBURBAN LAND       4513.92      45.14      5486.08      0.0     0.00001196
16   ARABLE LAND       6422.08      64.22      3577.92      0.0     0.00001478
17                        0.0        0.00         0.0       0.0     0.0
18    WORK UNITS      85477.56      99.90        84.66      0.0     0.00015135
19     AIR UNITS       5385.93      53.86      4614.07      0.0     0.0
20   WATER UNITS       5261.45      52.61      4738.55      0.0     0.0
```

FIGURE 16

REGIONAL RESOURCE DATA AT A CYCLE END

Funds and unit costs are in million dollar units.

Production units are scaled so that t=1 production is 1000.

Resource stockpile units are scaled so that t=1 reserve stock is 10,000 units, except for labor.

Additionally, at the end of the simulation, component inputs and outputs are presented in three table/graph sets, while resource usage appears in five table/graph sets. In all cases the data is presented as a ratio to the t=1 values, thus allowing simpler comparisions between the diverse categories.

In the Summary Set, columns three and four provide the annual expenditure of M&P funds for public components and private industry components, respectively. The actual statistic is:

where j ranges from 1-5 for public and 6-10 for private components.

Note that these values do not measure real output of goods but represent the relative level of funds committed to the components. Columns 6-10 provide similar composite measures of resource usage; in each case the statistic is analogous to the form above except actual units of usage are considered.

- Column six is average relative use of the 6 natural ores
- Column seven is average relative use of the 3 energy types
- Column eight is average relative use of the 2 agricultural resources plus the 3 land use categories
- Column nine is relative use of worker units
- Column ten is average use of treated effluent units of water and air media.

In the supporting table/graph sets these data are displayed in greater detail. In each case there is a column or symbol that provides the relative annual values for each component or each resource.

- Table Number Two provides the public sector output units.
- Table Number Three provides the private sector output units.

- Table Number Four provides the natural resource usage data.
- Table Number Five provides the energy and agricultural usage data.
- Table Number Six provides the work unit unemployment rate.
- Table Number Seven provides the land use and media treatment.

Step 3: Describe the State of the System

From Steps 1 and 2, much of the regional description is provided in terms of population and production growth, plus usage and present stock and unit cost levels for system resources. Step 3 completes the evaluation by comparing the current demand levels for goods and services to the annual output of the production components. The form to express population demand is development of a set of area specific measures giving per capita usage for combinations of outputs. The users (the per capita size) are expressed as total population or as one or more partitions of the population (see Step 1 for partition definitions). For each of these measures, a threshold, or minimum acceptable per capita output level, is set initially and adjusted as appropriate by the model operation. Comparison of the actual annual values for the measures with the thresholds allows expression of the region in terms of an ecosystem. Data provided can show:

- System resilience for each measure
- System processes acting as limiting factors
- The severity of the limiting processes
- Insight for adjustment of relative levels of the system processes.

The general flowchart of the Step calculations and examples is provided as Figure 17. Figure 18 gives data requirements ans sources.

Assumptions

It is assumed that all demands of the population can be translated into a series of demand levels for production goods and services. Hence, all measures can be set up as linear combinations of output levels divided by the consuming population size.

FIGURE 17

STEP 3 FLOWCHART

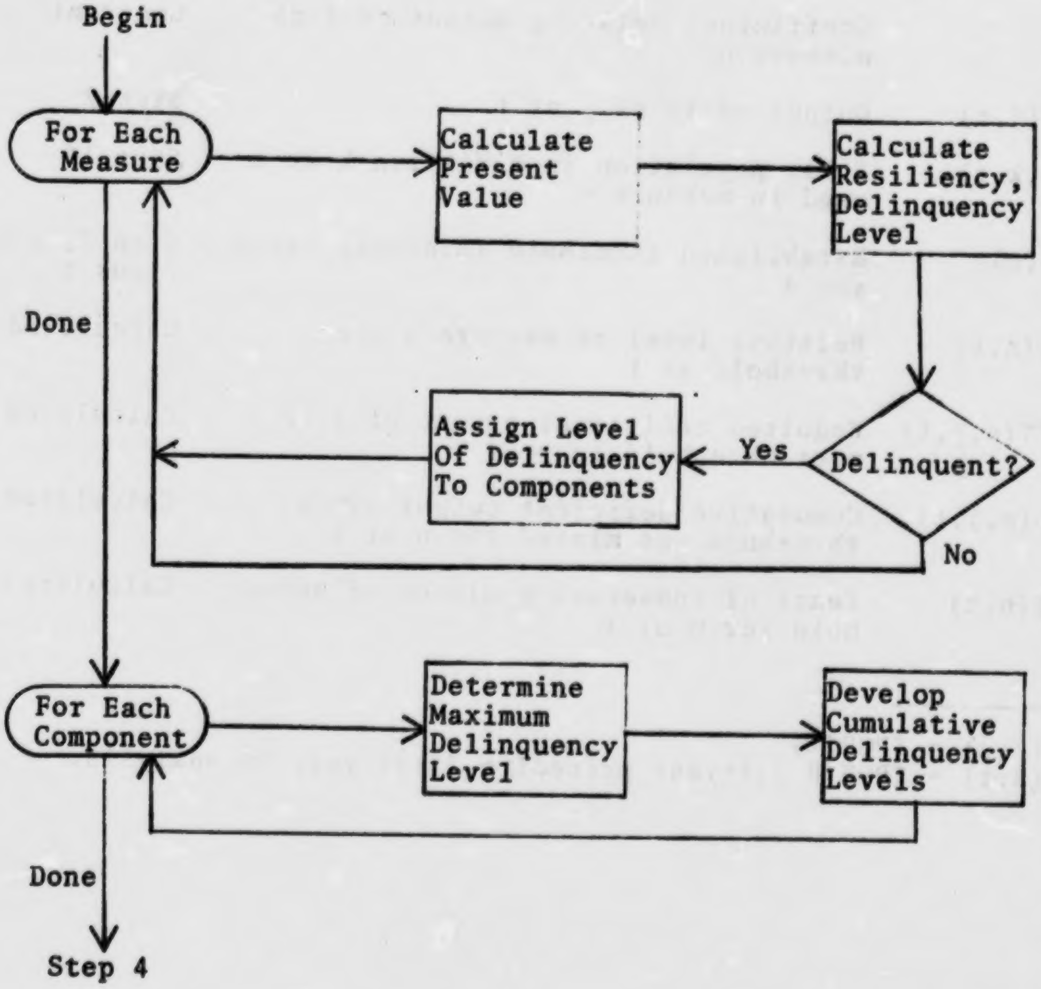

Begin
For Each Measure
Calculate Present Value
Calculate Resiliency, Delinquency Level
Delinquent?
Yes
No
Assign Level Of Delinquency To Components
Done
For Each Component
Determine Maximum Delinquency Level
Develop Cumulative Delinquency Levels
Done
Step 4

FIGURE 18

STEP 3 PARAMETERS

Name	Definition	Source
MEAS(n,t)	The value of the nth measure at time t	Calculated
Cnj	Coefficient relating output of j to measure n	Constant
OUTPT(j,t)	Output units of j at t	Step 2
POP(n,k,t)	Total population in partition k at t used in measure n	Step 1*
TMEAS(n)	Established threshold (minimum) value for n	Step 7, previous t
RESIL(n,t)	Relative level of measure n over threshold at t	Calculated
DOUTPT(n,j,t)	Required additional output of j to meet threshold in year t	Calculated
CFAIL(n,j,t)	Cumulative deficient output since threshold was missed for n at t	Calculated
COUNT(n,t)	Years of consecutive misses of threshold for n at t	Calculated

---

*POP(7,t) = TPOP(t)
POP(8,t) = TPOP(0),t=year preceding first year in analysis.

The form of the population demand thresholds are assumed to represent perceived needs; the level of need that is perceived is assumed to be a function of the past satisfaction of the demand. Therefore, if oversatisfaction has been maintained for a period of time (in SOS-1 set as two years) the threshold level will be increased to that past value. Similarily, if all adjustments of resources and funds distribution cannot produce a system that appears to regain resiliency, the levels of thresholds may be lowered until an absolute threshold level is reached.

It should be noted that the description of the State of the System does not require a arbitrary combination of the several measures into a single value. On the contrary, each measure allows measurement of a selected area of quality of life as described in demand satisfaciton terms. Since later Steps include adjustments within and between component outputs based on the relative resiliency shown for each measure value, it is appropriate to use a large set of measures, each measuring a discrete and narrow segment of demand satisfaction. Thus, although the set of measures will include demand for all component outputs, each measure should show demands for only one to three component outputs in order that the later adjustment processes can diagnose the problems as they exist in specific components.

While the set of measures must cover the spectrum of interests, it is not necessary that the measures be independent of each other. In fact, since the measures are not combined into a single scalar value, if one measure was the exact duplicate of another, no added weight is produced for this measure in the later Steps adjustment processes.

Algorithms

The first procedure of Step 3 calculates the present value assigned to each of the active measures for this time, t. All measures are of the form:

$$(32) \quad \mathrm{MEAS}(n,t)=\sum_{j}[\mathrm{Cnj}*\mathrm{OUTPT}(j,t)]/\mathrm{POP}(n,k,t)$$

where POP(n,k,t) is the assigned partition of population for measure n,
and $n=1,2,3,\ldots,15$.

To determine how well the value of the measure satisfies the population demands a test is made of the form:

$$(33) \quad \mathrm{kn}=\mathrm{MEAS}(n,t)-\mathrm{TMEAS}(n)$$

If k is greater than or equal to zero all required demand is satisfied and the system resiliency for measure n is set equal to the excess in output available to required output; this is computed as:

$$(34)\quad \mathrm{RESIL}(n,t)=\mathrm{Max}[0,kn/\mathrm{TMEAS}(n)]$$

If kn is less than zero the production system was unable satisfy all required demands associated with measure n. For the unsatisfied values a set of calculations are carried out to be used in later Step adjustment procedures. First for each component having a non-zero value for Cnj, there is assigned a pro rata delinquency of output:

$$(35)\quad \begin{aligned}\mathrm{DOUTPT}(n,j)&=[kn*\mathrm{POP}(k,n,t)]/Cnj \text{ if } Cnj\neq 0\\ &=0 \text{ if } Cnj=0\end{aligned}$$

The cumulative delinquency and time since the last year when MEAS(n,t) was resilient is calculated:

$$(36)\quad \mathrm{CFAIL}(n,t)=\mathrm{CFAIL}(n,t-1)+\mathrm{DOUTPT}(n,j)$$

$$(37)\quad \mathrm{COUNT}(n,t)=\mathrm{COUNT}(n,t-1)+1$$

For all measures where kn=0 the values of DOUTPT(n,t), CFAIL(n,t) and COUNT(n,t) are set to zero.

After all calculations associated with the individual measures are complete, a set of calculations to determine the maximum unsatisfied demand for output of each production component is carried out. For each component j, a test is made to determine the largest value of delinquency in output and the value of n associated with that value

$$(38)\quad N(j)=n[\underset{n}{\mathrm{Max}}[\mathrm{DOUTPT}(n,j,t)]]$$

Then for that value of n, the period and cumulated amount and years of delinquency are calculated:

$$(39)\quad \mathrm{DOUTPT}(j,t)=\mathrm{DOUTPT}(N(j),j,t)$$

$$(40)\quad \mathrm{CFAIL}(j,t)=\mathrm{CFAIL}(N(j),j,t)$$

$$(41)\quad \mathrm{COUNT}(j,t)=\mathrm{COUNT}(N(j),j,t)$$

It should be noted that if no level of delinquency was noted for j in any measures, then (39), (40) and (41) all yield zero.

MEASURE NUMBER	PRESENT VALUE	PRESENT RESILIENCE
1	2.4833	-0.0339
2	0.7963	0.1062
3	0.4391	-0.0980
4	1.0957	0.1255
5	8.2792	0.1305
6	0.5556	0.0538
7	1.0603	-0.1164
8	0.3842	-0.2108
9	0.0575	-0.8601
10	0.1097	-0.8950
11	0.0470	-0.9183
12	0.0	0.0

FIGURE 19

DEMAND MEASURES VALUE AND RESILIENCE

NOTE: See Figure 40 for data used in construction of each measure.

With the conclusion of Step 3 for a given year all elements of the regional system are described; thus the descriptive module of the SOS-1 system is completed.

State Description Outputs

If the cyclic output of Steps 1, 2 and 3 are not suppressed a tabulation of the values of each measure and the level of resilience or delinquency is produced as shown in Figure 19. Note that a negative value for resilience is equivalent to the level of delinquency.

THE SYSTEMIC MODULE OF A CYCLE

General Procedure

Within the first three steps of a cycle a number of elements may have been described as unsatisfactory when the system values were compared to its goals or thresholds. The next four steps provide a set of mechanisms for adjusting these components of our human ecosystem in order to adjust values this cycle or to reorient the system processes for subsequent cycle adjustments. Of these four steps, the next step, adjustment of the resource base, operates independently of the other adjustments. It is driven by its own special set of diagnostic signals, the resource stock depletion warnings, as developed in Step 2, equation (28).

The Steps 5, 6 and 7 are processed in a hirerarchical order to reduce the level of dissatisfaction of population demands within the human ecosystem. The hierarchy represented to meet these unsatisfied demands are:

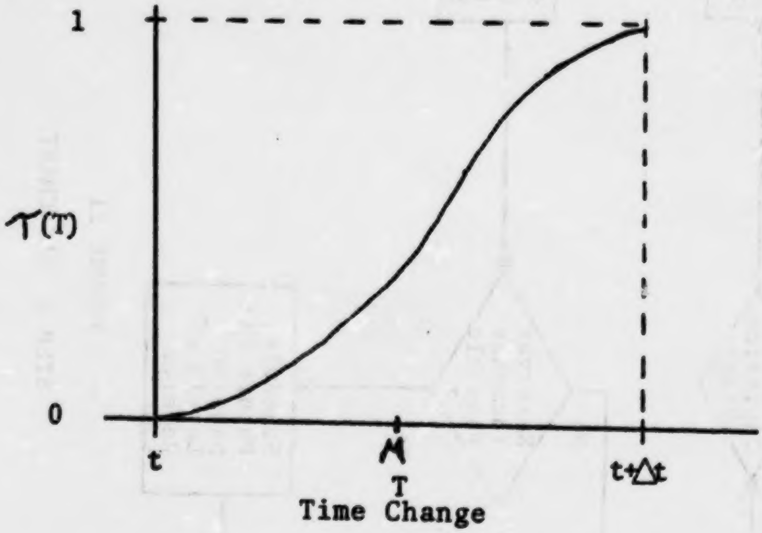
- Generate short term remedies by purchase of imports and delay of certain maintenance expenditures.
- Generate long term solutions by modifying production processes to use more economical production functions and by redistribution of M&P funds among sectors and among components.
- Lower the per capita demands of the consumers to reflect recognition that specific demands cannot be met at future times by the production sectors, and hence perceived needs will deminish if they are above the subsistance level.

If a previous step is forecast to reduce the problem area to an acceptable level, then the adjustments within the subsequent steps are not processed. If, however, the previous step does not appear to sufficiently reduce the level of unsatisfied demand, then the step is processed and the attempt to reduce stress levels is done independently of forecast adjustments of the previous steps, thus allowing the incidence of over-reaction.

Simulation of Long-Term Adjustment Timing

The procedures common to Step 4 and Step 6 include introduction of changes that do not occur at once but begin in the next cycle and undergo cumulative change to a maximum value over several annual cycles. The rate of introduction of these changes (or changeovers) is represented by a normalized cumulative normal distribution using the range $(-2\sigma, 2\sigma)$. The present time is equated to $t=M-2\sigma$ while the final time, $t+\Delta t=M+2$. The amount of change for any $t<T\leq t+\Delta t$ is provided as shown on the next page. A change from a level of procedure χ_1 to χ_2 would be set at time T by:

$$\chi(T)=\chi_2 * (L-\tau(T))+\chi_1 * \tau(T)$$



Interpolation Function

Specific processes using this relationship in the SOS Model are:

- Substitution of resources for a critical resource
- Expansion of resource reserves due to increased unit extraction prices.

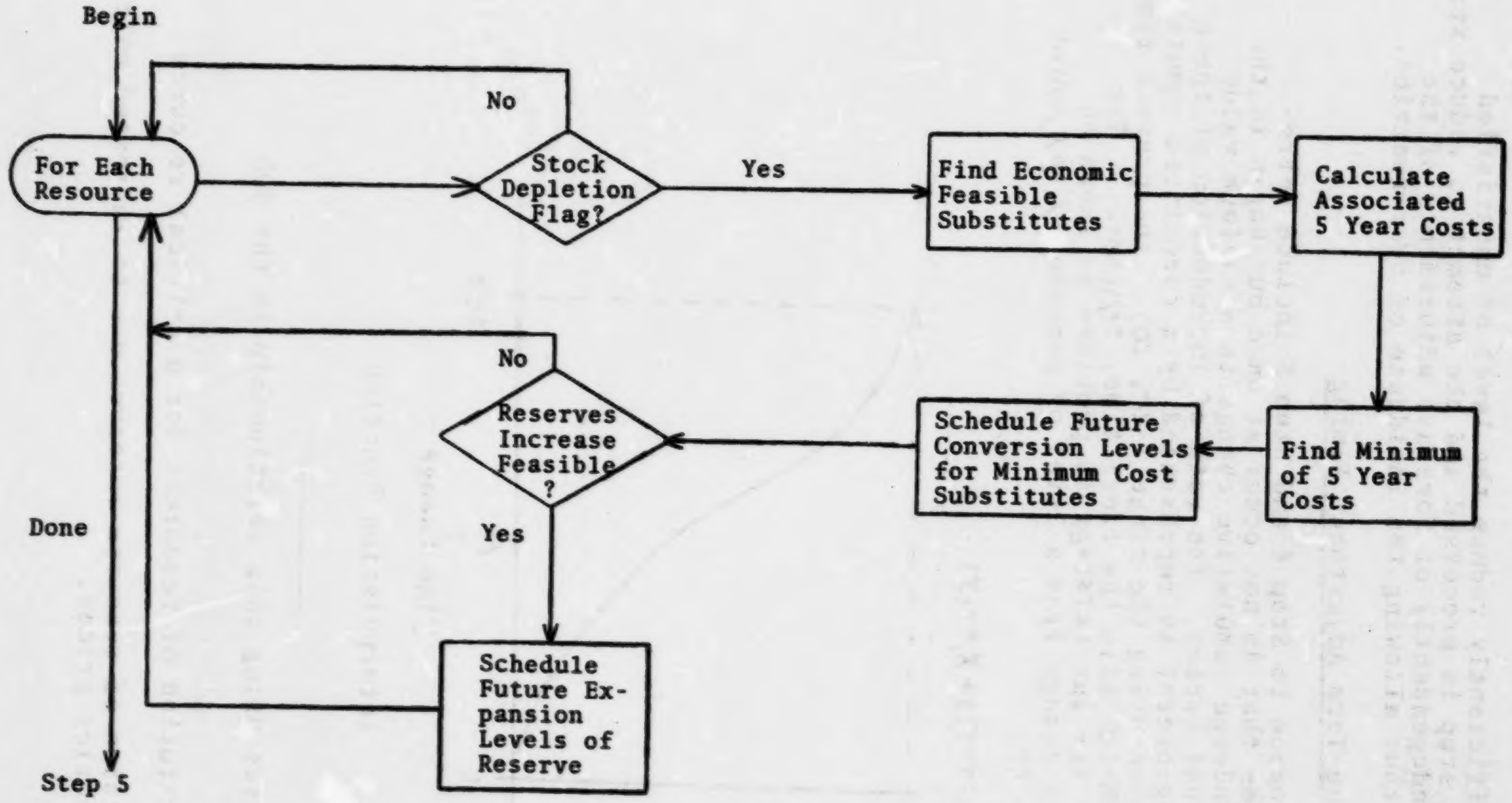

Begin
For Each Resource
No
Stock Depletion Flag?
Yes
Find Economic Feasible Substitutes
Calculate Associated 5 Year Costs
Find Minimum of 5 Year Costs
Schedule Future Conversion Levels for Minimum Cost Substitutes
Reserves Increase Feasible ?
No
Yes
Schedule Future Expansion Levels of Reserve
Done
Step 5

FIGURE 21

STEP 4 FLOWCHART

FIGURE 22

STEP 4 PARAMETERS

Name	Definition	Source
$\tau(t')$	Degree (fractional) of process transformation at time t'	Calculated
FLAG(r,t)	Condition of stock level signal of r at t	Step 2,t
SUBFOR(n)	nth substitution formula available	Constant
SBCST(r,n,t)	Unit cost of nth substitution at t	Calculated
C(r')	Units of resource r' in substitution for one unit of r	Constant (in SUBFOR(n))
MRCST(r',t)	Maximum unit cost of r' at t	Step 2,t
SB5CST(n,r,t)	Five year estimated cumulated unit cost for affecting substitution r at t	Calculated
CPILE(r,t)	Level of expansion of resource reserve stock given that expansion in feasible at t.	Constant

- Conversion from one production process to a lower cost process.

Elements of adjustment that do not require significant time delays (occur at least by next cycle) are:

- Deferral of capital maintenance for expansion of production funds.
- Increasing importation of component output.
- Transfer and reallocation of rates of M&P funds growth.
- Increase or reduction of demand measures.

Step 4: Adjust Resource Reserves and Utilization Factors

The fourth step of the cycle is processed only for those resources for which a critical stock depletion signal was set in Step 2 (i.e. FLAG(r)=1.0). For each such resource, the feasibility and economic utility of substitution, in whole or in part, and expansion of the reserve stockpile in reaction to increased unit extraction prices is simulated.

There exists a third adjustment of resource availability for durable resources not considered in this Step but automatically introduced in Step 2 calculations. The level of recycling of durable ores from production debris is increased from cycle to cycle as a function of change in unit procurement costs of the resource (see equations 21-22).

Figure 21 provides the general flowchart of Step 4 while Figure 22 lists the parameters of the algorithms and their sources.

Assumptions

Within any resource projection, the adjustment procedure will forecast data based on the maximum values at time t, rather than attempting to make non-linear projections of future values.

If a substitution for a resource by a mix of resources occurs in this step it affects the original utilization in all production components equally.

Once a substitution is initiated, the procedure will continue until it is completed. However, other substitutions can be initiated involving this resource and total change will be constructed across the hierarchy of initiated substitution changes.

A substitution need not completely replace the use of a resource; in fact, it generally does not. Typically a substitution includes the resource in its formulation but at a lower level than the amount for which the substitution is made.

If two substitutions are available and economically feasible, only one is initiated in a given cycle. The choice is based on selection of a minimum mean-unit-cost for an arbitrary period of time. In SOS-1 the time period is set as 5 years.

Algorithms

For each resource a test is made to determine if it has a critical stock depletion warning. For those resources in this condition the other algorithms of Step 4 are processed; for other resources no further action is taken in this Step.

For each resource r the test is made:

(42) FLAG(r,t)=1.0?

if yes, continue Step 4 for r;
otherwise process next r.

For each resource for which the test is positive, determine which, if any, of these substitution equations apply. For each applicable formula, check to make sure the substitution process is not presently underway. Additionally, for some resources the substitution can be done one time only. For those meeting the feasibility criteria calculate the present costs to substitute the new mix for a unit of resource and the projected five year resource unit costs for time-phased conversion. This procedure is stated below:

(43) Is substitution SUBFOR(n) for r? n=1,2,...,m
if yes, continue process
if not, do test for the next n

(44) Is SUBFOR(n) not in process?
if yes, continue process
if not, do test above for the next n

Calculate the two costs cited above.

$$\text{SBCST}(r,n,t)=\sum_{r'} \text{C}(r')*\text{MRCST}(r',t) \tag{45}$$

$$\text{SB5CST}(r,n,t)=\sum_{U=1}^{5} [\text{MRCST}(r,t)*(1-\mathcal{T}(n,u)) + \text{SBCST}(r,n,t)*\mathcal{T}(n,u)] \tag{46}$$

After all substitutions are tested and the successful ones have values for equations (45) and (46) developed, the appropriate substitution is selected or all are judged unacceptable. The acceptability is set by cost comparison to the resource procurement costs; the specific substitution selected is the minimum of the (5 years) cost alternatives.

For the test to be an economical substitution candidate:

(47) Is $SBCST(r,n,t) < MRCST(r,t)$
if yes, n is considered in set N below
if no, n is dropped from further consideration

For the minimum cost feasible substitution:

(48) Find $n = n[\underset{n \in N}{\mathrm{Min}} [SB5CST(r,n,t)]]$

Store in the Future Actions File (used in Step 8) for all times $\leq t+\Delta t$:

(49) $[r, n, \mathrm{time}, \tau(\mathrm{time})]$

After the procedure for substitution for a resource is complete, for each r in a stock depletion warning condition, check the feasibility of expanding the reserve stock level and if feasible, expand over time, the stocks by the prescribed amount.

(50) Is $CPILE(r,t) > 0$
if yes, continue
no, return to the initial action of Step 4 (test (42)) and the next r.

Store in the Future Actions File for all times $\leq t+\Delta t$

(51) $[r, CPILE, \mathrm{time}, \tau(\mathrm{time})]$

Also, set expansion of stocks to be infeasible until the cycle time equals $t+\Delta t$.

After test (42) and indicated subsequent actions of Step 4 are completed for each resource r, the SOS-1 program exits to Step 5.

Resource Availability Adjustments Output

For each cycle, the output of Steps 4, 5, 6 and 7 can be suppressed at the submission of a computer run by setting the program print option parameter, NPRNT2=2.0 (see Appendix 4).

```
**RESOURCE ADJUSTMENTS**

RESOURCE     SUBS.      STOCKPILE      YEAR
 NUMBER      NUMBER      INCREASE    COMPLETED
    4          4            0.0          7
    5          5            0.0          7
    4         0.0         2500.          7
    5         0.0         1000.          7
```

FIGURE 23

RESOURCE ADJUSTMENT FORMATS

NOTE: Figure 16 keys resource numbers to resource names.

If Step 4 output is not suppressed, a table of all resource adjustments for the cycle is printed as shown in the example in Figure 23. For each adjustment there is a line entry; therefore, for any resource up to two lines may be printed.

No adjustment procedures are shown explicitly in the table/graph sets at the end of the simulation.

Step 5: Perform Short Term Output Adjustments

After calculating the level of goods to be exported for each component in this cycle, a check is made to determine if the output levels of any component produced unsatisfied demand. For each component that had a delinquent output level a short term adjustment by deferring maintenance and using the funds for importing output is performed. For those components still delinquent, additional goods are purchased up to the available export balance level. If some components remain delinquent after these actions, Step 6 is processed; otherwise, the systemic module is complete and Step 7 is initiated to upgrade measure thresholds only.

Figure 24 depicts the general flowchart of Step 5 while Figure 25 includes all parameters used in the Step.

Assumptions:

For all components having resiliency, the export/internal consumption ratio will be maintained at the historical levels. Thus, system resiliency does not lead only to increased consumption over ecosystem thresholds, but also may be converted to cash flow within the export funds.

Imports of component output supplement internal production only up to threshold needs. Additional cash flow due to exports is accumulated for use as needed in later cycles.

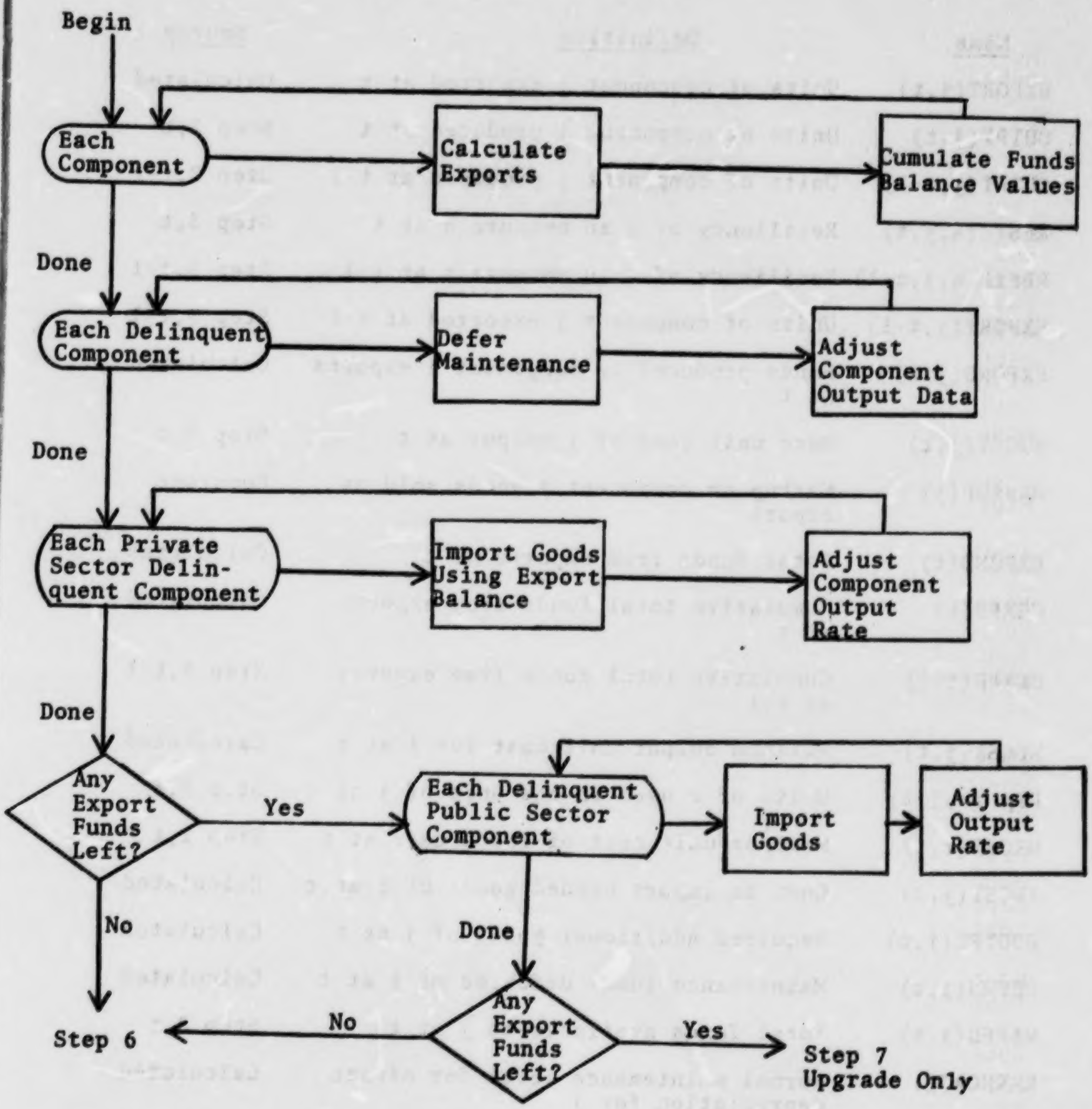
Deferred maintenance can be accomplished only on that element of maintenance associated with plant and equipment depreciation; facility expansion and ecosystem maintenance costs cannot be deferred.

No resilient components will defer maintenance to generate funds for importation of needed goods for other components.

Goods imported are imported at a cost to the maximum production costs if the goods were produced internally. Thus, no price break occurs by importation except that internal resource reserves are not depleted.

FIGURE 24

STEP 5 GENERAL FLOW CHART



Begin
Each Component
Calculate Exports
Cumulate Funds Balance Values
Done
Each Delinquent Component
Defer Maintenance
Adjust Component Output Data
Done
Each Private Sector Delinquent Component
Import Goods Using Export Balance
Adjust Component Output Rate
Done
Any Export Funds Left?
Yes
Each Delinquent Public Sector Component
Import Goods
Adjust Output Rate
No
Done
Step 6
No
Any Export Funds Left?
Yes
Step 7 Upgrade Only

FIGURE 25

STEP 5 PARAMETERS

Name	Definition	Source
EXPORT(j,t)	Units of component j exported at t	Calculated
OUTPT(j,t)	Units of component j produced at t	Step 2,t
OUTPT(j,t-1)	Units of component j produced at t-1	Step 2,t-1
RESIL(n,j,t)	Resiliency of j in measure n at t	Step 3,t
RESIL(n,j,t-1)	Resiliency of j in measure n at t-1	Step 3,t-1
EXPORT(j,t-1)	Units of component j exported at t-1	Step 5,t-1
EXFUND(j,t)	Funds produced by component j exports at t	Calculated
RUCST(j,t)	Mean unit cost of j output at t	Step 2,t
MARKUP(j)	Markup on component j goods sold as export	Constant
EXFUND(t)	Total funds from exports at t	Calculated
CEXFD(t)	Cumulative total funds from exports at t	Calculated
CEXFD(t-1)	Cumulative total funds from exports at t-1	Step 5,t-1
MOCST(j,t)	Maximum output unit cost for j at t	Calculated
UTIL(r,j,t)	Units of r used in one unit of j at t	Step 2,t
MRCST(r,t)	Maximum unit cost of resource r at t	Step 2,t
INCST(j,t)	Cost to import needed goods of j at t	Calculated
DOUTPT(j,t)	Required additional goods of j at t	Calculated
DEFMN(j,t)	Maintenance funds deferred of j at t	Calculated
M&PFD(j,t)	Total funds available to j at t	Step 2,t
RMNNOR(j)	Normal maintenance level for offset depreciation for j	Calculated
CFAIL(j,t)	Cumulative output failure level to date at t for j	Calculated
CFAIL(j,t-1)	Cumulative output failure level last year	Step 5,t-1

FIGURE 25 (CONT)

STEP 5 PARAMETERS

Name	Definition	Source
MDEFMN(j,t)	Maximum maintenance funds of j that can be deferred at t	Calculated
SINCST(s,t)	Cost to import all needed sector goods at t	Calculated
KFACT(j)	Normalizer of unit costs for component j	Step 2, Cycle 1

If importation occurs using the export balance, first all private production demands are fully met; then the residual funds are used to augment public output as needed.

Algorithms

The first calculations of Step 5 develop the levels of exportation of goods for the cycle based on the past trends and the current required use of a components output to meet system demands. After the export levels are set, the generated funds and the current export funds balance is calculated. First the calculation for amount of exports is:

$$(52)\quad \mathrm{EXPORT}(j,t) = \frac{\mathrm{OUTPT}(j,t) * \mathrm{Min}[\mathrm{RESIL}(n,j,t)]}{\mathrm{OUTPT}(j,t-1) * \mathrm{Min}[\mathrm{RESIL}(n,j,t-1)]} * \mathrm{EXPORT}(j,t-1)$$

Generated funds by exports of each component are:

$$(53)\quad \mathrm{EXFUND}(j,t)=\mathrm{RUCST}(j,t)*\mathrm{MARKUP}(j)*\mathrm{EXPORT}(j,t)$$

Funds cumulated over all components and added to the past balance are:

$$(54)\quad \mathrm{CEXFD}(t)=\mathrm{CEXFD}(t-1)+\sum_{j}\mathrm{EXFUND}(j,t)$$

After the export calculations are complete, the first set of short term adjustments for delinquent production components, $(\mathrm{DOUTPT}(j,t)>0)$, is begun. If no components are delinquent then Step 7 is initiated at this point, bypassing both the short-term and long-term component adjustments.

The first short-term adjustments are performed within the delinquent components only. Up to the level of required funds or the level of M&P funds used to offset plant depreciation, the maintenance funds are deferred and the funds are used to purchase needed imports for that component.

To determine the maximum funds needed for the component, first a maximum unit cost for the cycle is calculated:

$$(55)\quad \mathrm{MRCST}(j,t)=\mathrm{KFACT}(j)*\sum_{r}\mathrm{UTIL}(r,j,t)*\mathrm{MRCST}(r,t)$$

Then the total funds required by the component to supplement its production in the system is:

$$(56)\quad \mathrm{INCST}(j,t)=\mathrm{DOUTPT}(j,t)*\mathrm{MRCST}(j,t)$$

The maximum funds available by deferring maintenance is:

(57) $MDEFMN(j,t)=M\&PFD(j,t)*RMNNOR(j)$

If sufficient funds exist for the total adjustment, sufficient deferral is made to produce the necessary adjustment; otherwise all deferrable funds are deferred and the funds are used to reduce unit demands prior to entering the next set of adjustments.

(58) If $MDEFMN(j,t) \geqslant INCST(j,t)$ then the deferred funds are:

(59) $DEFMN(j,t)=INCST(j,t)$

and the residues for further need are:

(60) $DOUTPT(j,t)=0$

(61) $INCST(j,t)=0$

(62) $CFAIL(j,t)=0$

Otherwise if $INCST(j,t)>MDEFMN(j,t)$ the values are:

(59) $DEFMN(j,t)=MDEFMN(j,t)$

Residual needed output for j is:

(60) $DOUTPT(j,t)=DOUTPT(j,t)*[1-[DEFMN(j,t)/INCST(j,t)]]$

and residual funds needed are:

(61) $INCST(j,t)=INCST(j,t)-DEFMN(j,t)$

The remaining cumulative failure rate is recalculated as:

(62) $CFAIL(j,t)=CFAIL(j,t-1)+DOUTPT(j,t)$

If at the end of the deferral process above, no components continue delinquent, Step 7 is initiated. Otherwise, the second process of short term adjustment is initiated, as described below.

If any funds are available in the export funds balance, this fund can be used to augment imports as needed and as available. The process is performed first for components in the private sector.

Needed funds for private sector components are:

(63) $SINCST(priv,t)= \sum_{\iota}^{\ell} INCST(j,t)$

If SINCST is zero, proceed to the calculations for the public sector components. Otherwise, calculate

(64) k=Min[1,CEXFD(t)/SINCST(priv,t)]

The funds used for the private components will leave a residue of:

(65) CEXFD(t)=CEXFD(t)*[1-k]

Remaining residues for the delinquent components of the private stor are:

(66) DOUTPT(j,t)=[1-k]*DOUTPT(j,t)

(67) INCST(j,t)=[1-k]*INCST(j,t)

After these calculations are completed for all private sector components, a test is made of k. If it is equal to 1, sufficient export funds remain to determine if the public sector needs may be met. Otherwise, the simulation exits to Step 6, for long term adjustments.

If k=1, the total funds needed for the public sector components to meet needs are calculated:

$$(68) \quad \mathrm{SINCST(publ,t)} = \sum_{j=1}^{5} \mathrm{INCST(j,t)}$$

If SINCST is greater than zero, equations (64) through (67) are processed for public components. Then if k is not equal to one, Step 6 is initiated. If SINCST is zero or if k equals one, then Step 6 is bypassed since short-term adjustments are sufficient, and Step 7 is initiated only to upgrade thresholds.

Short-Term Funds Adjustment Outputs

If the output for each cycle of Step 5 is not suppressed, then a tabulation for each affected component of deferred maintenance funds and/or export funds expended for imports is printed. An example of the table is shown in Figure 26. Additionally, the level of the export funds not expended at the end of Step 5 is printed as shown in Figure 26.

Step 6: Perform Long Term Component Output Adjustments

If some components, after Step 5 short-term adjustments are performed, remain delinquent (DOUTPT(j,t) 0 at the end of Step 5), there is no further adjustment in this cycle that

```
SHORT TERM FUNDS ADJUSTMENTS

COMPONENT   MAINT.AMT      UNITS FROM
  NUMBER     DEFERRED      EXPORT BAL.
    2         1510.30           0.0
    8         2960.22           2.86
    9         1888.76           2.08
   10        20559.95           0.0
CUMULATIVE EXPORT BALANCE IS                   0.0
```

FIGURE 26

SHORT TERM ADJUSTMENT FORMATS

NOTE: Figure 15 keys component numbers to component names.

FIGURE 27

STEP 6 GENERAL FLOW CHART

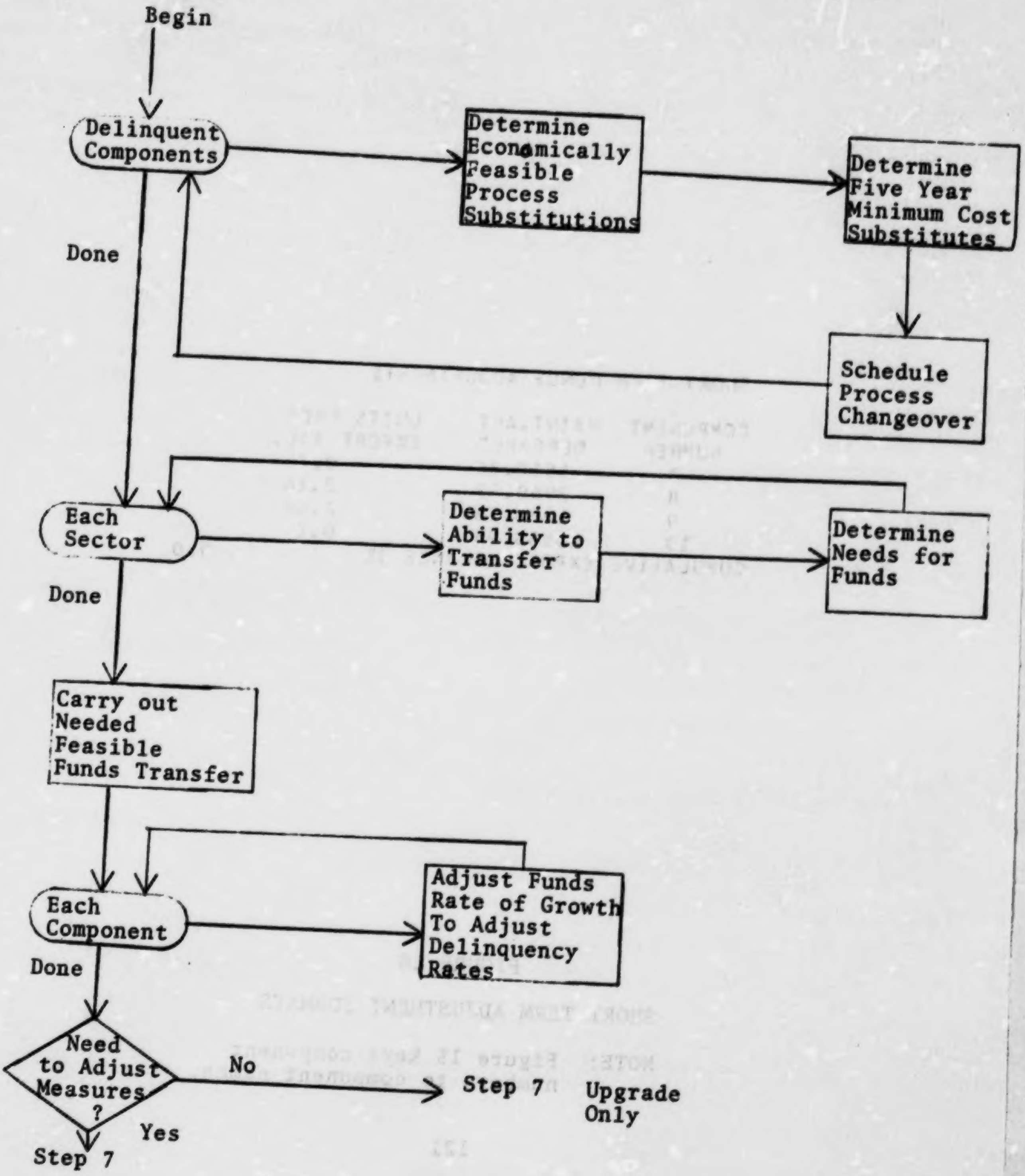

Begin
Delinquent Components
Determine Economically Feasible Process Substitutions
Determine Five Year Minimum Cost Substitutes
Schedule Process Changeover
Done
Each Sector
Determine Ability to Transfer Funds
Determine Needs for Funds
Done
Carry out Needed Feasible Funds Transfer
Each Component
Adjust Funds Rate of Growth To Adjust Delinquency Rates
Done
Need to Adjust Measures ?
No
Step 7
Upgrade Only
Yes
Step 7

FIGURE 28

STEP 6 PARAMETERS

Name	Definition	Source
SBCST(n,j,t)	Unit cost of substitute process n at t	Calculated
[AUTIL(n,j,r)]	Alternate resource use functions for j	Constant
MRCST(r,t)	Maximum unit cost of r at t	Step 2,t
MOCST(j,t)	Maximum unit output costs of j at t	Calculated
RT5CST (n,n',j,t)	Five year cumulated mean unit ccst beginning at t	Calculated
τ(n,t)	Change over time lag function	Calculated
M&PFD(j,t)	Total funds used by j at t	Step 2,t
RGROW(j)	Current funds growth rate for j	Step 7, previous t
M&PND(j,t+1)	Needed funds for j at t+1	Calculated
DOUTPT(j,t)	Additional output needed after short term adjustments of Step 5	Step 5,t
TPOP(t)	Total population at t	Step 1,t
TPOP(t-1)	Total population at t-1	Step 1,t-1
SCND(s,t+1)	Additional funds needed by sector s components	Calculated
TRNFD(s,t)	Set level of funds transfer to s	Calculated
SUMND(j,s,t+1)	Funds available from healthy components of s	Calculated
KFUND(s)	Pro rata adjustment of fund levels of components in s	Calculated
NEEDFD(j,t+1)	Funds needed above available levels for j at t+1	Calculated
SCNEED(s,t+1)	Total NEEDFD in s for delinquent j at t+1	Calculated
SCFUND(s,t+1)	Total funds available in s for resilient j at t+1	Calculated

can be performed in order to meet the population demands. However, several adjustments can be made over the long-term (succeeding periods) that are, over time, expected to reduce the level of delinquency. Three types of adjustment are possible:

- Reduction of production costs by introduction of new production formulas
- Reallocation of M&P funds within sectors
- Transfer of M&P funds between sectors.

Figure 27 provides the general flowchart and Figure 28 defines the parameters in Step 6.

Assumptions

All adjustments or transfer of funds are performed in the smallest neighborhood possible - within the component (Step 5), within the sector, and then between sectors. Within each neighborhood the adjustments are performed without regard to other neighborhood adjustments.

In the present form of SOS-1, available funds are generated based on the prevailing rates of growth and fund levels for each component. Reallocation of funds determine the total funds available for the next cycle and then change the rates of growth of components appropriately so that the total funds growth from t to t+1 is constant.

Algorithms

The long-term adjustments are performed in the order of adjustment of input/output formulas and then funds reallocation.

If any component which remains delinquent after Step 5, each of the available production formula alternatives are checked to determine if it is projected to lower unit production costs for any component. If a lower cost alternative exists, then a substitution process as detailed in Step 4 is affected.

First, calculating the substitution cost and the 5 year conversion costs for alternative production formulas:

$$(69)\quad SBCST(n,j,t) = \sum_{r} AUTIL(n,j,r)*MRCST(r,t)$$

if n is a substitution feasible for component j

(70) $$RT5CST(n,n',j,t)= \sum_{n=1}^{5} [SBCST(n,j,t)*[1-\tau(n,u)]+ MOCST(j,t)*\tau(n,u)]$$

(71) If $SBCST(n,j,t) < MOCST(j,t)$ and if $RT5CST(n,n',j,t)$ is the minimum for all candidate RT5CST, then it is introduced as a new production formula, and is stored in Future Actions File for all $t \leq t+\Delta t$ as:

(72) $$[j,n,time,\tau(n,time)]$$

In addition to the adjustment of production processes, if the long-term adjustment processes are entered, the algorithms for adjustment of growth rates between components are entered. These include adjustment of growth rates between components of a sector, and between sectors. The first action in these procedures is to calculate for each component the expected level of funds and the estimated level of funds required to produce sufficient output for demands.

Available funds are:

(73) $$M\&PFD(j,t+1)=M\&PFD(j,t)*[1+RGROW(j)]$$

Estimated required funds are:

(74) $$M\&PND(j,t+1)=M\&PFD(j,t)*\frac{TPOP(t)}{TPOP(t-1)}*[1+\frac{DOUTPT(j,t)}{OUTPT(j,t)}]$$

Then, for each component the required additional funds are:

(75) $$NEEDFD(j,t+1)=M\&PND(j,t+1)-M\&PFD(j,t+1)$$

If NEEDFD(j,t+1) is negative the amount represents the estimated level of funds that can be given up without causing component j to be delinquent in the next cycle.

The funds needed by, or available for transfer from, the sectors can be calculated as

(76) $$SCND(priv,t+1)= \sum_{j=6}^{10} [M\&PND(j,t+1)-M\&PFD(j,t+1)]$$

and

$$SCND(publ,t+1)= \sum_{j=1}^{5} [M\&PND(j,t+1)-M\&PFD(j,t+1)]$$

If both SCND are positive, sufficient funds exist in each sector to perform needed adjustments. If both SCND are negative, neither sector has sufficient funds for its own needs and hence cannot transfer funds to the other sector. In either of these cases, funds are not transferred and the process will skip to equation (80) for intra-sector adjustments. For the case where one SCND is positive and the other negative, inter-sector funds transfer is done. The level of funds transferred is the minimum value of the needed funds and the excess funds.

$$(77)\quad \text{TRNFD}(s,t+1)=\text{Min}[\text{SCND}(s,t+1)-\text{SCND}(s',t+1)]$$

where s is the receiving sector.

The funds are allocated to components in sector s on a pro rata basis using M&PFD(j,t+1) as the base.

For all j in s;

$$(78)\quad \text{M\&PFD}(j,t+1)=\text{M\&PFD}(j,t+1)*\ 1-\frac{\text{TRNFD}(s,t+1)}{\sum\limits_{j \in s}\text{M\&PFD}(j,t+1)}$$

The withdrawal of funds from sector s' are assigned on a similar pro rata basis:

For all j in s';

$$(79)\quad \text{M\&PFD}(j,t+1)=\text{M\&PFD}(j,t+1)*\ 1-\frac{\text{TRNFD}(s,t+1)}{\sum\limits_{j \in s'}\text{M\&PFD}(j,t+1)}$$

After these intersector transfers are completed, equation (75) is repeated for all j and then the process for intrasector transfers below is done.

Two totals are first calculated; the total funds required as an addition to delinquent components:

$$(80)\quad \text{SCNEED}(s,t+1)=\sum_{j \in s}\text{Max}[0,\text{NEEDFD}(j,t+1)]$$

and the total of funds available as an addition to delinquent component funds:

(81) $$\mathrm{SCFUND}(s,t+1)=\sum_{j\epsilon s} -\mathrm{Min}[0,\mathrm{NEEDFD}(j,t+1)]$$

Within a sector there are sufficient funds for all adjustments if:

(82) $$\mathrm{SCFUND}(s,t+1)>\mathrm{SCNEED}(s,t+1)$$

if so then

$$m=\frac{\mathrm{SCNEED}(s,t+1)}{\mathrm{SCFUND}(s,t+1)} \text{ and } n=1$$

otherwise

$$m=1 \text{ and } n=\frac{\mathrm{SCFUND}(s,t+1)}{\mathrm{SCNEED}(s,t+1)}$$

For components receiving additional funds:

(83) $$\mathrm{M\&PFD}(j,t+1)=\mathrm{M\&PFD}(j,t+1)+\mathrm{NEEDFD}(j,t+1)*n$$

and for components transfering funds:

(84) $$\mathrm{M\&PFD}(j,t+1)=\mathrm{M\&PFD}(j,t+1)+\mathrm{NEEDFD}(j,t+1)*m$$

For all components the new rate of growth, as a fraction, is:

(85) $$\mathrm{RGROW}(j,t+1)=\frac{\mathrm{M\&PFD}(j,t+1)}{\mathrm{M\&PFD}(j,t)}-1$$

After this calculation is complete for all components a test as to whether all components received adequate funds is made. If not, some measure thresholds in Step 7 may be lowered. Otherwise, only increasing thresholds are allowed in Step 7. This test completes all Step 6 actions.

Long-Term System Adjustment Outputs

If Step 6 cycle outputs are not suppressed, then two types of output may be produced (Figure 29). First, for changes in production processes, during the year in which the adjustment is made a printout giving component number, substitution process number and year of changeover completion is produced. Second, if any component has its rate of funds growth change, the new growth rate (in %) is printed for all components.

Step 7: Adjust Long Term Population Demands

The existing thresholds for a demand measure may be changed for either of two reasons. First, as a continuation of the system adjustment processes begun in Step 5, if the adjustments in neither Step 5 nor Step 6 can be projected to meet the

```
LONG TERM ADJUSTMENTS

COMPONENT   1: NEW I/O FORMULA NO.   2  : COMPLETE IN YR.  32
COMPONENT   5: NEW I/O FORMULA NO.   7  : COMPLETE IN YR.  27
COMPONENT   8: NEW I/O FORMULA NO.  14  : COMPLETE IN YR.  42
NEW FUND ANNUAL GROWTH RATES
 (COMPONENT NO. -- RATE)

 1-- 8.20    2-- 3.40    3-- 9.90    4-- 5.00    5-- 8.80
 6-- 4.96    7-- 4.20    8-- 2.18    9-- 2.73   10-- 3.47
```

FIGURE 29

LONG TERM ADJUSTMENT FORMATS

NOTE: Figure 15 keys component numbers to component names.

FIGURE 30

STEP 7 GENERAL FLOWCHART

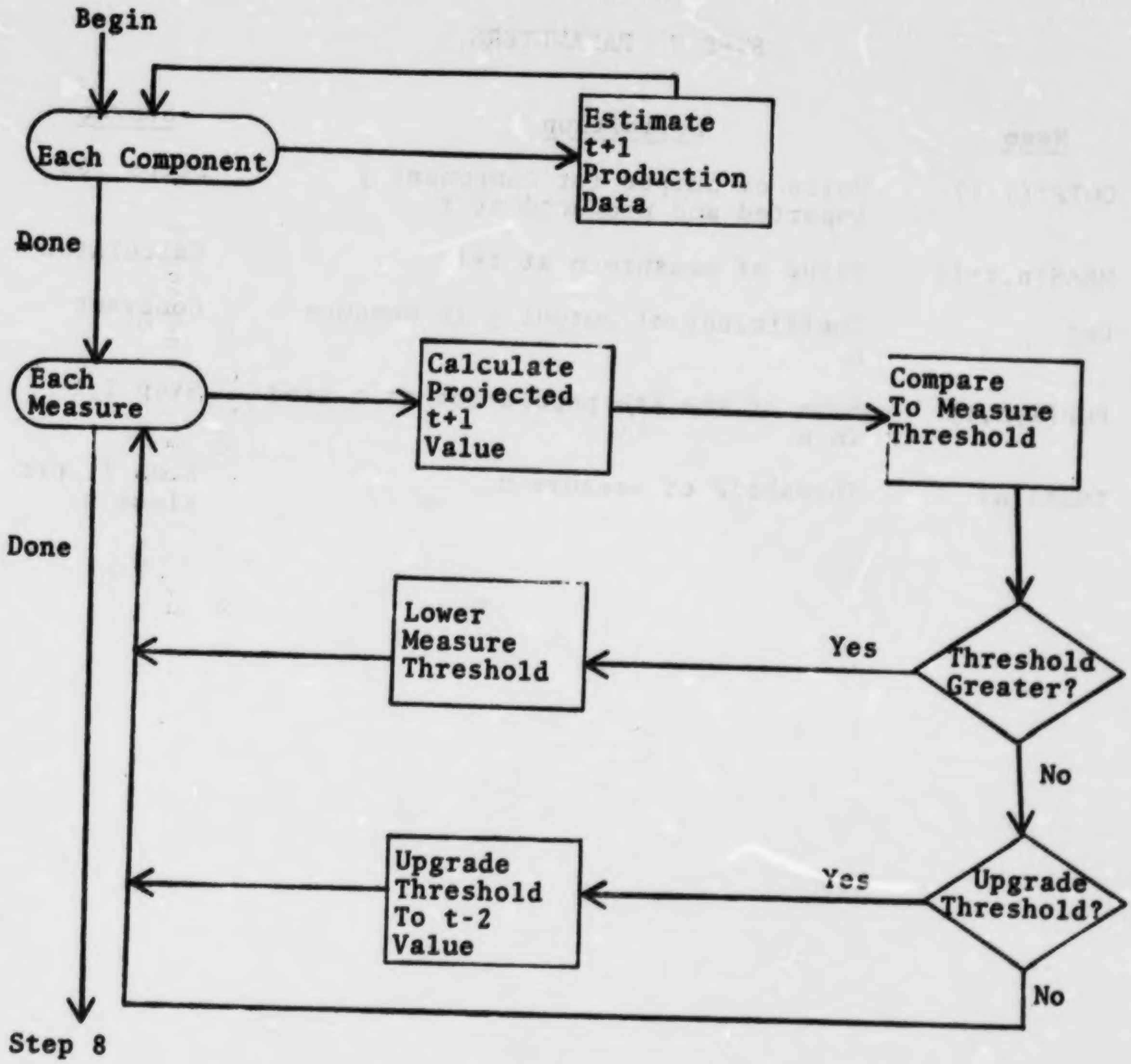

Begin
Each Component
Estimate t+1 Production Data
Done
Each Measure
Calculate Projected t+1 Value
Compare To Measure Threshold
Done
Lower Measure Threshold
Yes
Threshold Greater?
No
Upgrade Threshold To t-2 Value
Yes
Upgrade Threshold?
No
Step 8

FIGURE 31

STEP 7 PARAMETERS

Name	Definition	Source
OUTPT(j,t)	Units of output for component j imported and produced at t	Steps 2&5
MEAS(n,t+1)	Value of measure n at t+1	Calculated
Cnj	Coefficient of output j in measure n	Constant
POP(k,n,t)	Size of the kth population at t used in n	Step 1,t
TMEAS(n)	Threshold of measure n	Step 7, previous t

amount of a specific measure, its threshold may be reduced in Step 7 to reduce stress on the system. Secondly, however, if a measure has been above its threshold for a period of time, SOS-1 adjusts the threshold higher to reflect perceived needs and their increase due to availability of outputs above the threshold. The general flowchart and the included parameters are displayed in Figures 30 and 31.

Assumptions

Although Step 6 may have adjusted data for long-term change, Step 7 considers the data base as it exists at the end of the short-term adjustments (at the end of Step 5). Hence, a Step 7 degradation adjustment, with or without a Step 6 adjustment, should normally overcompensate for the past delinquency, causing a chance for the ecosystem to become resilient again.

The simulation of changing perceived needs are simulated in SOS-1 by increasing thresholds based on the arbitrary rule: If the measure has been above threshold for the last two cycles and has not decreased in that time, the new threshold is set to the measure value of two cycles ago. No decrease in thresholds is made until the adjustment procedures of Steps 5, 6 and 7 force the decrease.

Algorithms

If Step 7 is entered from Step 6 the following equations are processed in order for each measure. If another route of entry was followed, Step 7 will skip to action (89) for each measure in turn.

The first action is to estimate the value of the measure anticipated for next year. Thi[illegible] done using the same procedure as in Step 3 but the output level now includes the outputs imported as well as those produced internally. Secondly, a more severe requirement is set by assuming that the consuming population will grow by ten percent in the next year.

(86) $$MEAS(n,t+1) = \frac{\sum Cnj*OUTPT(j,t)}{1.1*POP(n,k,t)}$$

A test of the acceptability of the measure threshold is made next using the following test:

(87) Is $MEAS(n,t+1) < TMEAS(n)$

if so, proceed to action (88)
otherwise, go to action (89)

DEMAND THRESHOLD ADJUSTMENTS

MEASURE NUMBER	NEW VALUE	
	UPGRADE	DEGRADE
1	0.0	2.2734
2	0.7605	0.0
3	0.0	0.4035
4	1.0388	0.0
5	7.7738	0.0
6	0.0	0.5184
7	0.0	0.9893
8	0.0	0.3624
9	0.0	0.0602
10	0.0	0.1149
11	0.0	0.0588

FIGURE 32

DEMAND MEASURE THRESHOLD ADJUSTMENTS

NOTE: See Figure 40 for data used in construction of each measure.

Degrade the threshold of the measure n to:

(88) TMEAS(n)=Max[0.05,MEAS(n,t+1)]

(For the purposes of the initial tests of SOS-1, for every measure, the threshold of subsistance is arbitrarily set to 0.05.)

At this point the next measure is processed without doing action (89).

A two-level test is done to determine if the measure threshold should be increased:

(89) Is MEAS(n,t-1)>MEAS(n,t-2) and

is MEAS(n,t-2)>TMEAS(n)

if so, then

(90) TMEAS(n)=MEAS(n,t-2)

otherwise, TMEAS(n) remains the same.

After all measures are processed, Step 7 is complete and Step 8 is initiated.

Demand Threshold Outputs

If Step 7 output is not suppressed, any measure that has its threshold upgraded or degraded is tabulated with the new value placed under the appropriate type of action (see Figure 32).

CYCLE BOOKKEEPING

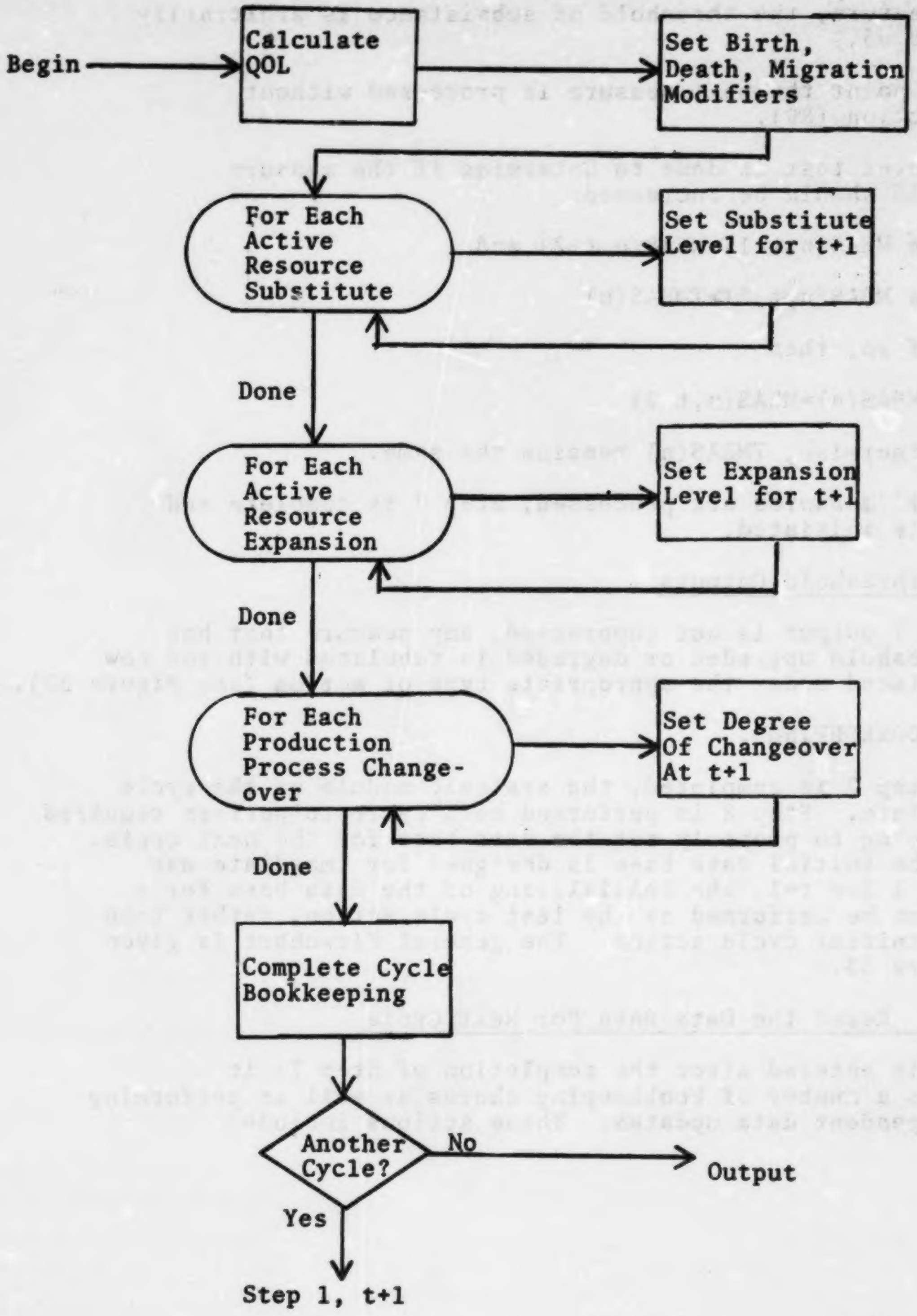
After Step 7 is completed, the systemic module of the cycle is complete. Step 8 is performed each cycle to perform required bookkeeping to properly set the data base for the next cycle. Since the initial data base is designed for immediate use in Step 1 for t=1, the initializing of the data base for a cycle can be performed as the last cycle action, rather than as the initial cycle action. The general flowchart is given in Figure 33.

Step 8: Reset the Data Base For Next Cycle

Step 8 is entered after the completion of Step 7; it includes a number of bookkeeping chores as well as performing time-dependent data updates. These actions include:

FIGURE 33

STEP 8 GENERAL FLOWCHART


Begin
Calculate QOL
Set Birth, Death, Migration Modifiers
For Each Active Resource Substitute
Set Substitute Level for t+1
Done
For Each Active Resource Expansion
Set Expansion Level for t+1
Done
For Each Production Process Change-over
Set Degree Of Changeover At t+1
Done
Complete Cycle Bookkeeping
Another Cycle?
No
Output
Yes
Step 1, t+1

- Calculating modifiers of the birth, death and migration rates
- Adjustment of the work force distribution among paid and unpaid workers
- Performing time-delayed adjustments of substitutions and stockpile expansions.

Additionally, Step 8 includes preparation of the output table/graph sets that are printed at the end of the run.

As part of the calculations for the birth, death and immigration rates, a linear combination of the demand measures into a quality of life scalar is used in SOS-1. The value is used only for this set of calculations, and then comes into play only when the values of the measures approach or pass below the subsistance thresholds.

Algorithms

The first set of calculations develop modifiers to the normal population rates based on the QOL scalar value, and for immigration, on the level of employment. These modifiers are applied as multipliers to the normal rates as defined as constants in the data base (see the next section).

The QOL scalar is a linear combination of the ratio of the individual measure values to their original thresholds.

(91) $\text{VALLQL}(t) = \nu_n * [\text{MEAS}(n,t)/\text{TMEAS}(0)]$

The birthrate modifier is:

(92) FBR = 1.0 if VALLQL>k/2
= 0.0 if VALLQL<k/4
=[[k/2-VALLQL]/k/4] otherwise

The deathrate modifier is:

(93) FDT = 1.0 if VALLQL>k/2
= 1.0+ k/4 if VALLQL<k/8
= 1.0+ k/4*[[k/2-VALLQL]/3k/8] otherwise

The net immigration modifier is:

$$
\begin{aligned}
(94)\quad FMG &= 1.0*k \text{ if } VALLQL>3k/4\\
&= 0.0 \quad \text{if } VALLQL<k/2\\
&= e*[1.-[[3k/4-VALLQL]/k/4]\ ] \text{ otherwise}
\end{aligned}
$$

where $e = 20*[ESTCK(r)-0.9]$
and r = labor.

Note that net immigration is the normal rate when employment is 95% and becomes out migration if employment is less than 90%.

The next calculation adjusts the total work force units ratio of paid versus unpaid work units due to the reserve of employment becoming close to fully consumed. In Step 2, work unit salaries begin to escalate if unemployment is less than 4%. Additionally, the following calculation draws unpaid workers into the paid labor force if unemployment is less then 4%. This is done by adjusting the partition coefficients for these two population partitions.

The unpaid partition value is:

$$(95)\quad a(j,6,y)=a(j,6,y)-a(j,5,y)*[ESTCK(r)-.96]$$

The paid partition value is:

$$(96)\quad a(j,5,y)=a(j,5,y)*[1+ESTCK(r)-.96]$$

The remaining calculations of Step 8 involve adjustment of resource availability, resource usage and production process changeover using the data stored in the Furture Actions File for t+1. These calculations were defined in Steps 4 and 6 and are not repeated here.

As the final action of a cycle of SOS-1, the time clock is advanced to t+1 and a check is made to see if the set of cycles is complete. If not, the next cycle is processed; otherwise, the summary data outputs are begun.

Step 8: Output

The scalar value of VALLQL for each period is output in two table/graph sets. The Summary Table includes value as a ratio to the first period value. Table Number Six provides the value as a ratio of the threshold level as the thresholds exist for the first cycle.

RUN OUTPUTS

While examples of each type of cycle outputs have been provided at the end of each subroutine description, a set of outputs that summarize possible cycle and run outputs may be helpful at this point. Appendix 9 provides a complete listing of all outputs for one test case that is discussed in the later section, Model Text. In particular, the cycle output for year 22 provides a list of all but one possible cycle outputs. The missing output, a resource substitution, is given in year 2 output. The final 16 pages provide a full set of run summary outputs.

SECTION VIII

EXAMPLE DATA

The initial operation of the model to test its adjustment characteristics draws upon a data base that is primarily United States data available for 1970. This section of the report discusses each data element as used in the basic case for the test of the SOS-1 Model. The data are organized as:

- population data
- resource data
- production component data
- demand measures data.

In each of these four elements the data are organized in the order in which the data are first used in the equations as processed in SOS-1.

POPULATION DATA

The population data allows development of the total population, the population first by age-year, and then grouped into four age-cohorts, and finally major consumer/work-unit partitions within the age cohorts.

Total Population

The total population for the year 0, the initial conditions, is set as 203,210 thousand people. The normal birthrate (BR) and normal deathrate (DT) are set as .0182 and .0094. The normal net migration rate for an unemployment rate of 5% is set as .0021. These and the later population data represent U.S. Census figures for April 1, 1970, as taken from the 1972 Statistical Abstracts of the U.S. The projection series is E, equivalent to a total reproduction index per mature female of 2.11.

These normal growth rates are subject to multiplicative modification as a function of the combined QOL demand value (VALLQL) of the past cycle (see equations (91)-(94) Section 7). Additionally, the net migration rate has a second multiplier based on the past cycle employment level. These functions are:

Birthrate

$$
\begin{aligned}
FBR &= 1.0 && \text{if } VALLQL > TQOL/2 \\
&= 0.0 && \text{if } VALLQL < TQOL/4 \\
&= 1-[(TQOL/2-VALLQL)/TQOL/4] && \text{otherwise}
\end{aligned}
$$

when TQOL is the initial combined measure threshold value.

Deathrate

$$\begin{aligned} FDT &= 1.0 && \text{if } VALLQL > TQOL/2 \\ &= 1.0 + C && \text{if } VALLQL < TQOL/8 \\ &= 1+C[(TQOL/2-VALLQL)/3TQOL/8] && \text{otherwise.} \end{aligned}$$

C in the initial runs is set equal to TQOL/4.

Immigration Rate

$$\begin{aligned} FMG &= F1MG*F2MG \\ F1MG &= 1 \text{ if } VALLQL > 3TQOL/4 \\ &= 0 \text{ if } VALLQL < TQOL/2 \\ &= 1-[(3TQOL/4-VALLQL)/TQOL/4] \text{ otherwise} \end{aligned}$$

$F2MG = (20*EMPR-18)$
where EMPR is the fractional employment rate for paid workers.

Age-Year Data

Additional data required to develop population by age-year and age-cohorts are the ranges of the age cohorts, the initial population and the normal deathrate for each age-year. The age cohorts are:

1-17	(immature, non-workers)
18-24	(young adults, normally in education or work units)
25-64	(working adults)
⩾65	(retired adults)

Figure 34 provides a list of these data.

Population Partitions

Within each of the four age cohorts, the resident population is subdivided into six mutually-exclusive partitions:

in education
in institutions
in non-working status
in training or welfare (unemployed)
in paid work status
in unpaid work status
(The partition selection is performed from the top; i.e., if the person qualifies in education he is considered for no other partition)

The development of partition size requires a coefficient matrix, the elements of which are multiplied by the output of goods by the appropriate component last cycle, to provide

Age Year	Population of Age-Year for Previous Year (thousands)	Age-Year Death Rate per 100
1	(calculated)	.0204
2-5	3430.8	.0008
6	3430.8	.0004
7-14	4581.3	.0004
15	3959.8	.0004
16-18	3959.8	.0013
19-21	3505.7	.0013
22-25	3545.0	.0013
26-35	2390.7	.0016
36-45	2308.8	.0031
46-55	2322.0	.0072
56-64	1859.0	.01660
65	1859.0	.05775
>65	20066.0	

FIGURE 34

POPULATION DATA BY AGE-YEAR

the partition population. These data are given in Figure 35. The values are equal to the 1970 data (scaled as thousands of people) for each partition and output component. As an example value: in age cohort 1, for each of the education units produced there are associated a population of 45,863. Since 1,000 output units are produced in 1970, the unnormalized education population size (equation (6) of the previous section) is 45.863 million school children less than 18 years old in publically operated schools.

RESOURCE DATA

For the initial operation of the model, 17 of the maximum of 20 entries for resources were used. While these resources represent surrogates in many cases, the range of characteristics in this set is considered reasonably comprehensive for the test of the example model. The simplified description of the categories, keyed to the SOS-1 resource index, r-1,2, ...,20 are:

1. Structural metals (iron, aluminum), in good supply at present unit costs
2. Copper, in fair supply at present unit costs
3. Lead and zinc, in good supply at present unit costs
4. Mercury, in poor supply at present unit costs but substitutes and presently non-economic reserves exist
5. Silver, in poor supply at present unit costs, little substitution available, fair non-economic reserves exist
6. Trace minerals and metals, in good supply and the most likely partial substitutes for mercury and silver
7. Coal, in good supply but not a preferred energy source
8. Oil, in poor supply, little substitution possible, but good non-economic reserves exist at present
9. Electricity, supply level is static but annually renewable, substitution is conversion of plants to consume coal (represents 1970 stock of electricity producing sources)
10. Not used
11. Fibers (lumber is surrogate) in fair supply, renewable over a long period

FIGURE 35

POPULATION PARTITION COEFFICIENTS

	Output Component Name									
PARTITION NUMBER	EDUCATION	TRANSPORTATION	HEALTH	DEFENSE & ADMIN	WELFARE	LGT POLL IND	HVY POLL IND	COMMERCIAL	AGRICULTURE	HOUSE & RECREATION
	AGE GROUP 1									
1	45,863	0	0	0	0	0	0	5,528	0	0
2	0	0	372	0	0	0	0	104	0	0
3	0	0	0	0	0	0	0	0	0	17,654
4	0	0	0	0	122	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
	AGE GROUP 2									
1	5,550	0	0	0	0	0	0	1,714	0	0
2	0	0	153	0	0	0	0	52	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	415	0	0	0	0	0
5	825	675	499.35	1880.25	39.15	3500.4	2546	2,546	519.3	17.1
6	0	0	0	0	0	0	0	0	0	2,101
	AGE GROUP 3									
1	0	0	0	0	0	0	0	0	0	0
2	0	0	415	0	0	0	0	0	156	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	743	0	0	0	0	0
5	4,675	3,825	2829.65	10654.75	221.85	19835.6	10249	10249	2942.7	96.9
6	0	0	0	0	0	0	0	0	0	22911.55
	AGE GROUP 4									
1	0	0	0	0	0	0	0	0	0	0
2	0	0	496	0	0	0	0	726	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	18836	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0

12. Food, in good supply, renewable annually, surplus level is fixed as a function of agriculture production levels.

13. Not used

14. Urban land, in good supply, easily increased by substitution

15. Suburban land, in good supply, easily increased by substitution

16. Arable land, in good supply, level is fixed or decreasing only, in 1970 one-third is held as soil bank

17. Not used

18. Paid worker units, function of population characteristics, initial unemployment level is moderate

19. Treated air, static quantity, in good supply as a renewable value

20. Treated water, static quantity, in good supply as a renewable value.

Resource Supply and Cost Data

Associated with each resource at any time is the initial economically available resource level (the reserve stockpile for a given unit cost), the level of the resource used to date prior to cycle 1 of SOS-1, the level of recycling accomplished, set by the prevailing unit prices, the mean and maximum unit prices and the present annual use rate. Several of these values are composites of more detailed data. Each statistic is defined to its detailed elements and the data elements are listed in Figure 36.

Initial resource levels for all resources except paid-work-units are set arbitrarily as 10,000 units. For example, if iron is a surrogate for structural metals, all reserves of all materials of the category are totalled and then are assumed to equal 10,000 times the level of stocks that have not been depleted. For iron this is 10,000 times .99 or 9,900 units available in the reserve stockpile.

For paid workers, the reserve level is the paid worker partition size, in thousands.

The stock level used to date is the fraction of the 10,000 units that have been consumed and are non-renewable at the present time. For annually renewable resources this value is zero since each of these is assumed annually renewable in its entirety.

Present unit cost for a resource is set by first determining the maximum unit price at the projected level of use for the cycle, and then developing a mean unit price from this maximum value and the previous year's maximum value. The level of usage for any cycle can be calculated from the projected levels of production output for the cycle (see the production data discussion). From this the used stockpile at the end of the cycle (ESTCK(R)) can be obtained. The maximum unit price is:

$$\mathrm{MRUCST(R)=(K1(R)+(K2(R)*ESTCK(R))}^{\mathrm{K3(r)}}\mathrm{)*ESCAL*.00001}$$

when ESCAL is set by equation (24) of Section 7. and K1(R), K2(R) and K3(R) are given in Figure 36.

The values for K1(R) and K2(R), as well as the initial stock level were selected primarily to produce changes in costs during the first few cycles that appear to be appropriate for the surrogates in the next few real-time years. Thus for silver the initial cost when the stockpile is 5000 units is $(0 + .948*.5)^2$; after another 1000 units are used then the cost is $(.948*.6)^2$; an increase of 44%. Additionally, the initial values were scaled so that the costs in production for a given resource type would be typical of its share in the present production-costs structure in the component outlays, using data from the U.S. Statistical Abstract.

The recycling rate for a non-renewable ore represents that fraction of the ore that can be obtained from recycling debris from earlier production processes (output no longer in use). The rate used at any time is obtained from:

$$\mathrm{REREC(R)=K4(R)+(K5(R)*ESTCK(R))}^2$$

For all of the resources used in the initial tests K4(R) was set equal to 0.0 (negligible recycling). The values for K5(R) are given in Figure 36 and represent conservative estimates of recycling capabilities with today's technology.

	INITIAL USED LEVEL PRIOR TO t=1	K1	K2	K3	K5	FLGDAT(K) 1	2	3	4	CPILE
1	.01	4.9	4.9	2	0.0	.3	.6	.92	.95	5000.
2	.25	4.0	32.0	2	0.75	.3	.6	.92	.95	5000.
3	.20	0.8	5.2	2	0.8	.3	.6	.92	.95	5000.
4	.50	0	.132	2	1.0	.6	.75	.92	.95	2500.
5	.50	0	.948	2	0.6	.6	.75	.92	.95	1000.
6	.01	.079	.158	2	0	.3	.6	.92	.95	10000.
7	.05	0	320.8	2	0	.3	.6	.92	.95	5000.
8	0	7.33	58.7	2	0	.3	.6	.92	.95	5000.
9	0	2.00	11.19	2	0	.6	.75	.92	.95	0
10	---	----	----	--	----	--	---	---	---	----
11	0	16.7	16.7	2	.45	.6	.75	.92	.95	0
12	0	26.4	26.4	2	0	.9	.87	.92	.95	0
13	---	----	----	--	----	--	---	---	---	----
14	0	1.0	1.0	2	0	.8	.87	.92	.95	0
15	0	1.0	1.0	2	0	.8	.87	.92	.95	0
16	0	1.0	1.0	2	0	.8	.87	.92	.95	0
17	---	----	----	--	----	--	---	---	---	----
18	0	5.00	5.9	2	0	.9	.92	.95	.98	----
19	0	0	0	2	0	--	---	---	---	0
20	0	0	0	2	0	--	---	---	---	0

FIGURE 36

GENERAL DATA FOR RESOURCE CATEGORIES

Note that no recycling is considered for renewable resources for the test case; in the general case this restriction can be lifted without altering the model algorithms.

The present annual use rate for resources is a function of the production processes. The determination of the level of resources that are withdrawn from the existing reserve stockpile vis-a-vis produced by the recycling process from production debris is obtained from the values of the initial stockpile for the cycle, the associated recycling ratio and the projected level of use of ores during the cycle.

Resource Usage Adjustment Date

As resources are used, thus depleting the available stockpile, a set of tests are made to determine if the level of resources have reached a depletion level that is critical enough to project a expansion of the available stockpile; (i.e., extraction of neglected ores now become economic due to a rise in unit sales prices) or to have all production processes substitute, partially or completely, for a resource in short supply.

To select the times when a resource is considered to be in short supply, four points of stockpile depletion are set for each nonrenewable and renewable resource. In any cycle where one of these points (VFLG(L)) is past or if the stock depletion is greater than .985, the search for economic adjustments is initiated. The four values used for the test case are given in Figure 36.

If a stock depletion point is past, two contingencies are checked. One of the resource checks determines whether the existing stockpile reserve can be increased. This can occur if the incremental size of the stockpile is greater than zero and if an increase is not presently underway. The increase of stocks to the new level is assumed to take five years. The incremental stockpile size (CPILE) assumed for the test cases is shown in Figure 36.

The second resource check determines if there are one or more substitutions available to reduce the usage of the resource. If any exist, the least costly for the next five years is selected. In the test case, once a substitution for a nonrenewable resource is done, it cannot be made again. Each substitution that is activated is initiated during the next cycle and takes several years to be fully implemented. Figure 37 provides the initial set of substitutions and the associated time factor. As an example, substitution 9 allows a change in use of urban land by any production process that uses urban

FIGURE 37

RESOURCE SUBSTITUTIONS

Substitute For	Substitution	Years to Complete
1. Copper	.32 units of iron and .6 units of copper	5
2. Copper	.55 units lead, 1. units trace metal, .6 units copper	10
3. Lead	.15 units iron, .9 units lead	5
4. Mercury	.4 units mercury, .06 units trace	5
5. Silver	.2 units silver, .06 units trace, .2 units coal	5
6. Fibers	.5 units fiber, .1 units trace	3
7. Oil	.02 units coal, .6 units oil	2
8. Electricity	.02 units coal, .3 units electricity	10
9. Urban Land	.9 units of urban land, .03 units suburban land	1
10. Suburban Land	.9 units of suburban land, .05 units arable land	1

land. The substitution is, for every unit of urban land (as existant in 1970) that is used formerly, .9 units of urban plus .3 units of suburban (1970 census) can be used. Note that the unit sizes are not equal.

COMPONENT PRODUCTION DATA

The resource utilization and the production of outputs for regional consumption and for export requires data including:

- annual funds projected for maintenance and production
- maintenance rates for capital expansion, capital maintenance and environmental maintenance
- historical export fraction
- resource utilization formulae for production of one unit of output (both active and alternative formulae)

Funds Data

The initial level of production and maintenance funds and the initial annual rate of funds growth are input for each production component. These values are shown in Figure 38. M&P funds are in millions of dollars; rate of growth as a percentage. Data are taken from official U.S. figures; 1970 for the level; the 1950-1970 data for the real dollar funds growth rates.

Maintenance Data

The cost to create a new plant complex that is sufficient to produce one unit of output on a scale where the output for a component is 1000 units annually, (CAPVL), is given in Figure 38 in millions of dollars. Hence an investment of this amount will increase the production component capital 0.1%.

The normal annual cost to maintain the existing plant and capital complex for production of output is given as a percentage of the M&P funds; this is given in Figure 34 as MNRNOR.

The cost to maintain environmental media quality assumes that 1000 units of each media are naturally cleaned during any year. All other media units that are polluted by the production processes must be treated at a unit cost that

	Education	Transportation	Health	Defense & Admin.	Welfare	L Poll Ind.	H' Poll Ind.	Commercial	Agricul-ture	House & Recreation
M&PFUND ($)	56900	14000	25000	108600	145300	203400	129000	43600	85000	293700
R Growth (%)	8.2	3.4	9.9	5.0	8.8	4.7	4.6	2.2	0.3	3.8
CAPVL ($)	90	10	100	200	300	400	250	100	200	706
MNRNOR (%)	2	5	3	3	3	3	4	4	2	3
QOLT (%)	0	0	0	2	0	10	3	7	5	4
EJOT (%)	0	0	0	0	0	20	30	10	20	0

FIGURE 38

GENERAL DATA FOR PRODUCTION COMPONENTS

is set as a fraction of the operating expenses to produce one unit of treated, clean media (QOLT). Hence, if agriculture causes one unit of polluted water for each production unit, 5% of its operating funds may be used for water treatment. Figure 38 provides these values as used in SOS-1.

Export Data

Since the level of exports depends in part on the historical export levels, a percentage of goods produced that were exported in the cycle must be initially entered. These are labelled EJOT in Figure 38 and reflect data trends from 1960-1970.

Resource Utilization Data

For each production component a present production formula-- usage of each resource type to produce one unit of output -- plus alternative production formulae are entered. Each entry consists of the number of units of each resource to be used for one unit of output (scaled by 1000), an indication as to whether the formula is initially in use, and a time in years required to fully implement a change to a nonactive formula. Figure 38 provides these data.

Looking at column 3 of Figure 35, the production component (2) is transportation. the use of resource 1 (iron) to produce one unit of output is 20 (scaled to .02 for one unit). Thus in 1970 when transportation output is 1000 units, the use of iron is 20 units of the present stockpile, which earlier was set at 9,900 units of ores. If resource row one (iron ore) is added across for active formulas the total annual usage is 200. Hence the predicted (statically) annual depletion is about 1/50 of the reserve, and transportation will use about one tenth of that.

DEMAND MEASURES DATA

The calculation of the 11 demand measures used in the initial SOS-1 runs require development of the coefficients associated with production output, an initial threshold value for the measure (TMEAS), and selection of the population base (DN) to be used in selecting the per capita size. When the set of measures are combined into a scalar to set the birth, death and immigration modifiers a weighting factor (VN) is required. All data are given in Figure 40. The values of Cnj are scaled by (10^5).

As examples of the measure constructions, measures 1 and 2 reflect education satisfaction. For measure 1 the population considered (DN) is school attendence, while 2 relates the

	COMPONENT NUMBER																
Resource	1	1	2	3	4	5	5	6	6	6	7	7	8	8	9	9	10
1	0	0	20	0	0	0	0	140	140	140	20	20	0	0	20	20	0
2	0	0	0	0	0	0	0	225	225	125	25	25	0	0	0	25	0
3	0	0	32	32	32	0	0	160	160	160	32	32	0	0	32	32	0
4	0	0	0	300	0	0	0	200	100	100	200	400	0	50	100	100	200
5	0	0	0	500	0	0	0	400	500	500	0	0	100	50	0	0	0
6	0	0	0	40	0	0	0	10	10	10	10	10	10	10	10	10	20
7	4.5	4.5	4.5	4.5	0	0	0	18.2	18.2	18.2	4.5	4.5	4.5	4.5	4.5	4.5	4.5
8	45	45	90	45	0	0	0	45	0	0	90	45	45	45	90	135	45
9	800	1600	0	800	400	400	800	400	400	400	400	800	800	1200	400	800	400
11	0	0	0	0	0	0	0	0	0	0	150	150	50	150	0	0	300
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1600	1600	6400
14	0	0	1500	0	0	0	0	0	0	0	0	0	750	750	0	0	4500
15	0	0	400	0	0	0	0	400	400	400	400	400	400	400	0	0	2400
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7000	7000	0
18	11200	5600	13000	2800	14000	11200	5600	2800	2800	2800	2800	2800	11200	11200	5600	5600	0
19	0	0	2000	0	0	0	0	2000	1000	500	0	0	0	0	0	0	1000
20	0	0	0	0	0	0	0	625	0	0	1250	625	0	0	1875	625	1250
Active?	Y	N	Y	Y	Y	Y	N	Y	N	N	Y	N	Y	N	Y	N	Y
Years	15	10	10	30	20	5	5	15	15	5	15	15	20	20	20	20	20

FIGURE 39

PRODUCTION FORMULAE FOR COMPONENTS INPUTS

	MEASURE NUMBER										
Component Number	1	2	3	4	5	6	7	8	9	10	11
1	806	806	0	0	0	0	0	0	0	0	0
2	0	0	1000	0	0	0	0	0	0	0	0
3	0	0	0	1000	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1000	0	0	0	0	0	0
6	0	0	0	0	0	500	500	0	0	0	0
7	0	0	0	0	0	500	500	0	0	0	0
8	194	194	0	0	0	0	0	1000	0	0	0
9	0	0	0	0	0	0	0	0	1000	1000	0
10	0	0	0	0	0	0	0	0	0	0	1000
DN	1	7	7	7	4	7	5	7	7	5	7
VN	.08	.08	.08	.10	.10	.10	.06	.08	.13	.06	.13
TMEAS	1.26	.35	.40	.40	3.5	.45	1.20	.35	.30	.75	.35

FIGURE 40

DEMAND MEASURES DATA

measure to a total population per capita measure. The relative contributions of the 10 production components are 80.6% from government operated education, 19.4% from private schools (assigned to the commercial sector) and none from other components. In 1970 when all component output was 1000 units and total population is about 200 million, the measure 2 value is:

$$\frac{(1000(.806)+1000(.194))\times 10^5}{200,000,000} = .50$$

Since the threshold is .35, education is exceeding its lowest required value; here, by a resilience level of (.50-.35)/.35= .42.

These measures provide a major driving force for adjustments of funds and resource usage in SOS-1. Because of this, in a policy analysis, considerable care is needed in setting each measure to reflect a discrete population goal or interest that is representative of the region under analysis. In measure development the following guidelines should be observed:

- Each of the measures should represent a discrete area of the production processes. If a measure is set up that includes all or many component outputs as contributors and, for a run, it becomes delinquent, this forces each of the included components to attempt to expand output. Thus, a general measure can cause attempts that overcompensate and that signal that the majority of the output areas are in trouble when the actual cause is much more localized.

- Not all components need to be included in the set of measures; however, if a component measure is not included in at least one measure, then there is no driving force to make it boost funds for output as resource costs grow. On the other hand, even if it is not included it does contribute to adjustments in terms of adjusting output formulas or resource substitutions. Thus it acts as a component having a set pattern of growth that is not changed by population preferences but that does act as a user of resources and a recipient of technological change.

- Each measure has equal weight in the adjustment process and is independent of all other measures; hence, each measure can be constructed without regard to other measures as long as the set of measures includes a non-zero coefficient for each output component that should be sensitive to regional desires.

- Initial threshold values for measures should be set relative to the known initial measure values to represent the level of initial relative stress patterns. For example, if all output areas other than education are considered adequate, the example data thresholds might have been set so that the resilience of measures 1 and 2 were -.10 and all others were .15. This would have caused in cycle 1 immediate pressure to boost educational and commerical (private school) output.

For the test data, the set of measures were derived for two purposes; to provide typical measures for a national region and to provide a full set of construction types. The set can be interpreted as:

1. Education output per full time student - a measure of educational quality change for students.
2. Education output per capita - a measure of educational availability and quality for full time and part time students.
3. Transportation output per capita - a measure of transportation improvement as a per capita value.
4. Health output per capita - a measure of health services per capita for the total population.
5. Welfare output per welfare recipient - a measure of welfare services per recipient.
6. Manufacturing output per capita - a measure of goods supply per individual.
7. Manufacturing output per worker - a measure of goods production compared to personal income level.
8. Commercial output per capita - a measure of availability of services per capita.
9. Agricultural output per capita - a measure of food availability compared to consuming population.
10. Agricultural output per worker - a measure of food and fiber compared to personal income level.
11. Household and recreational output per capita - a measure of supply of shelter and recreation per capita.

SECTION IX

MODEL TEST

The example model, SOS-1, has been operated over a set of closely allied data bases that have, as initial data, values that are generally representative of the United States in 1970. The use of data bases with small variations has allowed analysis:

- to verify that the simulation reacts credibly,
- to develop insights as to model sensitivity to data variation, and
- to determine the most useful avenues for further model development and application.

A series of seven simulation runs were made for use in the example analysis of model output included in this section; additional simulation runs were made to support the supplementary analyses of appendixes 6-8. All runs used the algorithms and data base of SOS-1 and the previous section except for exceptions as noted in the discussion of each run. Since the output of a single run of 25 years is at least 66 pages, only one full set is reproduced in this report. This run, the Base Case, uses the documented data base and algorithms exactly and is reproduced as Appendix 9.

THE TEST CASES

For the purposes of model testing and use in example analyses, several sets of parametric variation of a single statistic or algorithm were made. In the body of this report, the analysis is confined to detailed discussion of the output of the Base Case Run plus comparison of the output of seven runs in which the only data variation is the rate of annual growth in funds used for operating and maintaining the production components.

Other areas of variation from the Base Case Run are briefly discussed in appendixes. These are:

- Appendix 6 - maintaining learned gratification levels (thresholds of quality of life measures) at initial values to increase later year adjustment flexibility.
- Appendix 7 - setting the gross population birth and death rates equal (ZPG for non-migrant population).

- Appendix 8 - removal of systemic adjustment algorithms, thus reducing the Base Case to a rigid consumption system that allows no change of usage levels or rates except resource procurement costs.

THE BASE CASE

Run 1, using the example data of the previous section, represents a severe case for the testing of adjustment procedures of the model. This high stress level is caused by three primary factors:

- The trends of investment growth as projected using the period 1950-1970 are maintained, thus allowing a regional capability of rapid expansion (an annual rate of 4.9 percent) of operating funds. This trend should cause rapid depletion of scarce resources and perpetuation of relative growth patterns among production components.
- The birthrate is maintained throughout the twenty-five year period at about twice the death rate. Over 25 years the unconstrained population growth rate would be 32.4%, to 269 million, causing the demand for production output to increase at least at this rate. (This growth rate is equivalent to U.S. Census Series E growth projections.)
- The per capita demand rates have required gratification levels that automatically increase if the appropriate production components have supplied goods above the threshold rates. Thus, not only is the demand increased due to a larger consumer population but may also because of increased satisfaction of previous per capita demands.

During the 25-year base case simulation, the model made numerous adjustments and significant short-term trauma occurred. Yet, even the rather rudimentary set of adjustments of this data base allowed support of the population growing at a rate close to the projected unconstrained level, and provided goods to meet levels of demand well above the initial annual values. The total population change over the 25 years was 31.4%, or 97% of the level projected for population growth that is unconstrained by productivity.

In the gross analysis of demand satisfaction, after 25 years, the annual investment growth rate of nearly 5% has increased the composite demand satisfaction to

1.8 times the original value. However, this value is a combination of 11 submeasures that have not increased in a smooth pattern. Figure 41 provides the value of the individual measures for years 1, 10, and 25.

	t=1		t=10		t=25	
MEASURE NUMBER	PRESENT VALUE	PRESENT RESILIENCE	PRESENT VALUE	PRESENT RESILIENCE	PRESENT VALUE	PRESENT RESILIENCE
1	1.6899	0.3412	2.2150	0.1107	4.7121	0.2079
2	0.4868	0.3908	0.5742	0.0598	1.3598	0.2203
3	0.4868	0.2170	0.4114	-0.1549	0.4797	-0.0145
4	0.4868	0.2170	0.7148	0.1815	2.0432	0.1840
5	4.8139	0.3754	5.9868	0.1088	18.0411	0.5002
6	0.4868	0.0818	0.4786	-0.0168	0.6634	0.0645
7	1.2491	0.0409	1.2328	0.0274	1.5814	0.0520
8	0.4868	0.3908	0.3742	-0.2312	0.4056	-0.1669
9	0.4868	0.6227	0.3780	-0.0603	0.2945	-0.2680
10	1.2491	0.6655	0.9737	-0.0484	0.7019	-0.3140
11	0.4868	0.3908	0.5944	0.1140	0.5932	-0.1558
12	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 41

DEMAND SATISFACTION AT t=1, 10, AND 25

Comparing t=10 to t=1, six of the eleven measures have decreased. By t=25, the number of reduced measures is to four. Greatest increases are in measures 1, 2, 4, and 5. These reflect increased output per capita in the areas of education, health and welfare (see Figure 40) while output/capita in the other seven production areas have fallen or remained about the same. These three very healthy areas reflect areas that have a high annual investment growth rate (<8%) and low use of natural and land resources. Comparing t=25 to t=1, the values reflect that the production components of transportation, commercial, agriculture, and household have maintained output growth rates lower than the population growth rate. Thus, while the gross measure of satisfaction has shown an increase, many of the individual measures indicate areas of regional production weakness. Additionally even the combined measure has shown a

rate of growth that is much less than the growth in funds during the period.

Figure 42 provides a comparison of remaining resource stockpiles and resource unit procurement costs for years t=1, t=15, and t=25. In several resource categories the available resource stockpiles have increased over the 25 year period; e.g. lead, zinc. In this case, the penalty for having increased resources is an escalating unit cost, up 24 percent at t=15 and 64 percent at t=25. The resources with the most dramatic cost increases are silver (essentially a depleted resource by t=25), food, coal, oil, and work unit costs. Each of these resources contributed to major fluctuation or depression of production output during the run. With the exception of silver, all stocks are acceptable at t=25 but this has been achieved for eight resource categories by increased unit costs in excess of 30% over the initial costs.

In Appendix 9, a complete listing of all simulation outputs plus the summary statistics for the Base Case Run is given. Review of those outputs shows that the region made the following number of system adjustments.

Adjustment Type	Number
Increase of stockpile	19
Substitution for resources	9
Importing of scarce goods	19
Change of production formula	3
Redistribute investment funds growth	2
Demand Threshold:	
Upgrade	78
Downgrade	0
Salary increase	3

FIGURE 43

ADJUSTMENT STATISTICS, RUN 1

In Run 1 a volatile situation occurred, yet at the end of 25 years a reasonably healthy economy existed, population growth was maintained and only one resource was effectively depleted. In order to provide an appreciation as to the methods of adjustments and the immediate outcomes, the following narrative of Run 1 major events is provided:

In year 2, the smooth expansion of the economy to date caused the threshold values of 8 to 11 measures to increase. However, two major problem areas also surfaced. A depletion

```
                              t=1                           t=15                          t=25

     RESOURCE         REMAINING   THIS CYCLE   REMAINING   THIS CYCLE   REMAINING    THIS CYCLE
NO.       NAME        STOCKPILE   UNIT COST    STOCKPILE   UNIT COST    STOCKPILE    UNIT COST
 1             IRON    9700.00    0.00004902    9358.77    0.00005366   12226.09    0.00005596
 2           COPPER    7250.00    0.00006000   13255.06    0.00006768   16891.32    0.00006768
 3        LEAD,ZINC    7680.00    0.00001000   13841.02    0.00001237   12948.29    0.00001637
 4          MERCURY    4000.00    0.00000110    3514.32    0.00000110    1044.70    0.00000291
 5           SILVER    4000.00    0.00000329     904.78    0.00002011      12.66   12.4825945
 6      TRACE METAL    9800.00    0.00000790    7353.83    0.00000790   19647.29    0.00000790
 7             COAL    4950.30    0.00080901    4046.83    0.00111401    6092.96    0.00117728
 8              OIL    9505.00    0.00011000    8964.30    0.00016290    4334.81    0.00035416
 9      ELECTRICITY    5200.01    0.00004580    4766.95    0.00005957    5397.71    0.00005957
10                        0.0     0.0              0.0     0.0              0.0     0.0
11           LUMBER    9959.99    0.00016700    9959.99    0.00016700    9868.56    0.00[illegible]701
12             FOOD    9999.99    0.00033000    9843.48    0.00033000     975.37    0.00049139
13                    10000.00    0.0          10000.00    0.0          10000.00    0.0
14      URBAN LAND     3250.01    0.00001846    1844.53    0.00001930    2812.84    0.00001930
15   SUBURBAN LAND     6000.00    0.00001816    4195.85    0.00001866    2501.47    0.00001924
16     ARABLE LAND     8000.00    0.00001822    9546.88    0.00001844    9497.56    0.00001844
17                        0.0     0.0              0.0     0.0              0.0     0.0
18      WORK UNITS     5455.32    0.00010330      89.57    0.00017259     111.99    0.00017259
19       AIR UNITS     5000.01    0.0           4258.46    0.0           2191.42    0.0
20     WATER UNITS     5000.01    0.0           4409.83    0.0           3264.02    0.0
```

FIGURE 42

RESOURCE STATUS DATA t=1, 15 AND 25, RUN 1 warning for both mercury and silver caused an expansion of the economically available stockpiles for both plus the initiation of partial substitute resource usage formula for both. Also in this year, the low unemployment rate caused a work unit cost increase of 20%.

In year 3 the effects of higher work unit costs and the increase in demand thresholds caused a temporary strain on output needs. The salary change caused output to be depressed about 25%, causing in turn seven demand thresholds to be missed. This deficiency was fully met in year 3 by seven production components deferring capital maintenance and by importation of some goods in two component areas. Full long-term adjustment of funds to counter the depressed output took several more years.

Also in year 3, a stock depletion warning for copper caused a small stockpile increase plus a substitution adjustment. This substitution with the two previous resource substitutions caused a higher use of iron and zinc, lead, and a much higher use of trace minerals.

In year 4, although the thresholds of 5 measures were missed, the thresholds of 2 other measures were upgraded.

In year 7, low unemployment again escalated work unit costs, this time an additional 15%. Two production components deferred maintenance while 4 demand thresholds were upgraded. The first energy shortage, oil, was signalled causing higher usage of coal as a substitute.

From year 9 to year 15, depletion warnings and adjustments occurred for iron, copper, mercury, zinc-lead, silver, trace minerals, land and electricity. In each case the warning was early enough and adjustment procedures flexible enough to alleviate the situation by a short term adjustment.

From year 19 to year 22, silver underwent large unit cost increases. These costs depressed the output levels of two components 40% by year 22. Also from 19 to 22 food costs increased 50%. The effects of the silver and food unit costs of year 22 caused the following problems:

- five outputs depressed
- eight demand thresholds missed
- the export fund balance exhausted without meeting all import needs

- three production components adjusted component production formulas
- annual investment growth funds were redistributed to attempt long-term balancing of problems.

Since the silver shortage did not affect all production outputs; two demand thresholds were upgraded even in this year of general economic stress.

By year 25 the large set of adjustments to the silver and the food shortage were sufficient so that only one production component required use of export funds.

The narrative above indicates that SOS-1 does include capabilities to adjust to needs; the primary deficiencies of the model output appear to be that the escalating prices require better interpolation procedures. The primary data deficiencies of the small adjustment data base for this test are the number of available substitutions and the need to introduce improved non-linear stockpile data.

The summary data for the Base Case, in which the efforts of the problem areas of the narrative above can be noted, follow (Figures 44-51). These figures are also used in the parametric analysis that follows this Base Case analysis.

Findings that appear appropriate for the Base Case--and its associated data base assumptions--are:

- The region is able to maintain an adequate base to support the population and its demands for the 25 year time period.
- While certain problems near the end of the run period suggest that a longer simulation period may see significant regional degradtion, the data deficiencies may overly accent these. Specifically, an expanded set of substitutes might reduce the need for silver ore and an agricultural rate of growth greater than .3% might allow for improved food output.

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (C)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0100	1.0000	1.0000
2.	1.0211	1.0848	1.0371	1.0310	1.0478	1.0450	1.0270	1.0504	1.0308
3.	1.0325	1.1612	1.0670	0.8296	0.8302	0.8321	0.9469	0.7976	0.8631
4.	1.0342	1.2302	1.0884	0.9636	0.9500	0.9645	1.0169	0.9506	0.9599
5.	1.0442	1.3402	1.1261	0.9918	1.0090	1.0161	1.0369	1.0031	0.9917
6.	1.0544	1.4769	1.1657	1.0285	1.0503	1.0670	1.0641	1.0636	1.0295
7.	1.0663	1.5851	1.2056	1.0548	1.0920	1.1133	1.0900	1.1138	1.0543
8.	1.0794	1.7094	1.2631	0.8748	0.9098	0.8901	1.0289	0.8773	0.9168
9.	1.0824	1.8195	1.2906	1.0143	1.0586	0.9942	1.0935	1.0495	1.0174
10.	1.0945	2.0174	1.3363	1.0528	1.1262	1.0580	1.1239	1.1172	1.0512
11.	1.1071	2.1841	1.3831	1.0878	1.1777	1.1057	1.1537	1.1801	1.0836
12.	1.1215	2.3592	1.4511	0.9061	0.5870	0.9395	1.0972	0.9384	0.9499
13.	1.1257	2.5277	1.4934	1.0600	1.1678	1.1358	1.1716	1.1204	1.0593
14.	1.1403	2.8152	1.5470	1.1055	1.2628	1.2662	1.2075	1.2096	1.0951
15.	1.1550	3.0372	1.6048	1.1451	1.3614	1.4158	1.2459	1.2789	1.1332
16.	1.1700	3.2941	1.6867	1.1959	1.5018	1.6095	1.2863	1.3578	1.1844
17.	1.1851	3.5823	1.7427	1.2467	1.6394	1.8443	1.3284	1.4416	1.2225
18.	1.2005	3.8883	1.8080	1.3013	1.7550	2.0512	1.3689	1.5319	1.2666
19.	1.2161	4.2057	1.8725	1.3559	1.9441	2.2446	1.4099	1.6239	1.3164
20.	1.2318	4.5535	1.9405	1.4136	2.0912	2.4518	1.4549	1.7229	1.3549
21.	1.2478	4.9514	2.0116	1.4583	2.2280	2.6108	1.4181	1.8309	1.3635
22.	1.2639	5.3795	2.0940	1.3034	1.5574	2.2721	1.2165	1.8499	1.1559
23.	1.2803	5.8179	2.1535	1.5168	2.4740	2.9227	1.2063	2.0652	1.3253
24.	1.2969	6.2952	2.2487	1.7338	2.6421	3.5155	1.2961	2.1966	1.3981
25.	1.3137	6.6859	2.3369	1.8205	2.8169	3.8390	1.3468	2.3210	1.4545

STATE OF THE SYSTEM

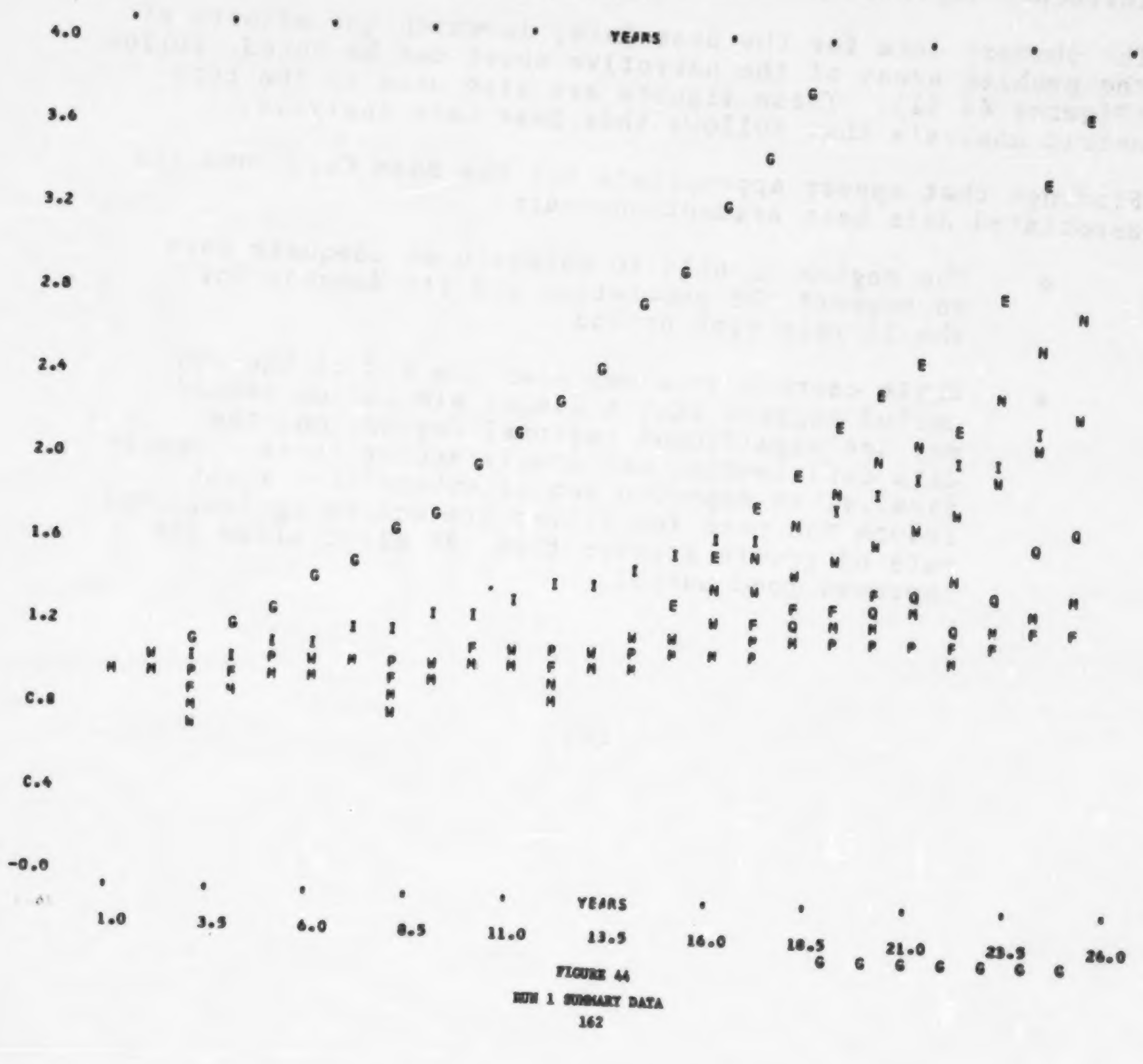


FIGURE 44

RUN 1 SUMMARY DATA

TABLE NUMBER ONE - POPULATION
(SCALED TO ORIGINAL VALUE)

YEAR	TOTAL POPULATION (P)	UNDER 18 YEARS (1)	18-24 YEARS (2)	25-64 YEARS (3)	OVER 64 YEARS (4)
1.	1.0109	0.3417	0.1237	0.4435	0.1019
2.	1.0211	0.3407	0.1258	0.4498	0.1048
3.	1.0329	0.3403	0.1282	0.4570	0.1075
4.	1.0342	0.3367	0.1291	0.4596	0.1087
5.	1.0442	0.3331	0.1345	0.4659	0.1107
6.	1.0544	0.3296	0.1358	0.4724	0.1125
7.	1.0663	0.3268	0.1455	0.4797	0.1142
8.	1.0794	0.3245	0.1490	0.4899	0.1159
9.	1.0824	0.3193	0.1512	0.4956	0.1162
10.	1.0945	0.3170	0.1547	0.5058	0.1171
11.	1.1071	0.3145	0.1582	0.5140	0.1200
12.	1.1215	0.3135	0.1590	0.5262	0.1228
13.	1.1257	0.3151	0.1526	0.5337	0.1243
14.	1.1403	0.3197	0.1476	0.5461	0.1269
15.	1.1550	0.3246	0.1425	0.5586	0.1293
16.	1.1700	0.3297	0.1374	0.5713	0.1315
17.	1.1851	0.3351	0.1322	0.5842	0.1336
18.	1.2005	0.3397	0.1280	0.5972	0.1355
19.	1.2161	0.3444	0.1238	0.6105	0.1374
20.	1.2318	0.3492	0.1257	0.6179	0.1391
21.	1.2478	0.3540	0.1277	0.6255	0.1406
22.	1.2639	0.3588	0.1300	0.6331	0.1421
23.	1.2803	0.3637	0.1324	0.6407	0.1435
24.	1.2969	0.3687	0.1351	0.6483	0.1449
25.	1.3137	0.3737	0.1369	0.6569	0.1462

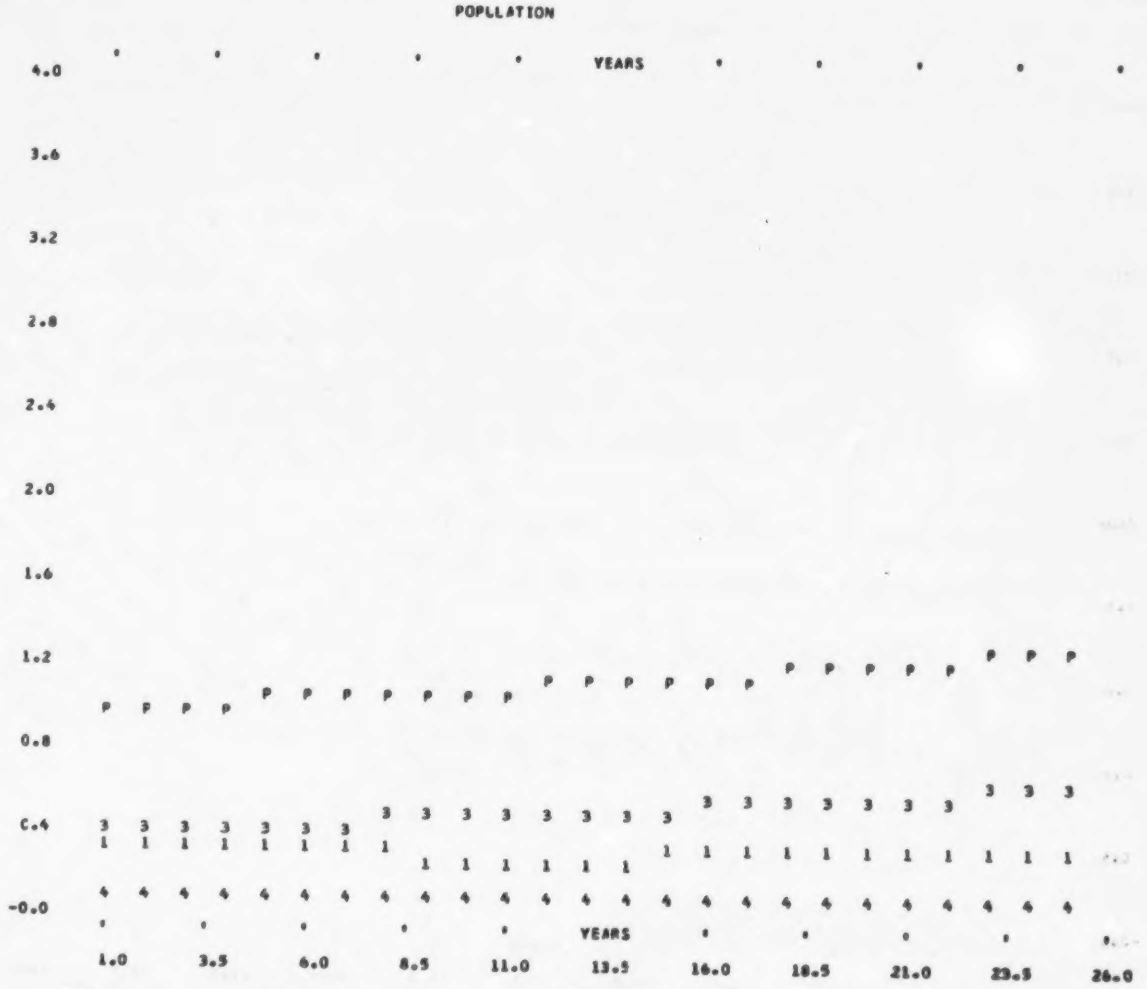


FIGURE 45
RUN 1 POPULATION DATA

TABLE NUMBER TWO - PUBLIC SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	EDUCATION (E)	TRANSPORTATION (T)	HEALTH (H)	DEFENSE AND OTHER (D)	WELFARE (W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0819	1.0328	1.0906	1.0500	1.0880
3.	0.8308	0.7644	0.8580	0.7785	0.8323
4.	1.0294	0.8803	1.0657	0.9560	1.0313
5.	1.1146	0.9102	1.2039	1.0042	1.1237
6.	1.2245	0.9411	1.2963	1.0546	1.2503
7.	1.3089	0.9725	1.3892	1.1047	1.3411
8.	1.0417	0.7438	1.1412	0.8479	1.0668
9.	1.2768	0.8846	1.4066	1.0285	1.3073
10.	1.3841	0.9150	1.5858	1.0800	1.4629
11.	1.5167	0.9459	1.7046	1.1329	1.5792
12.	1.2167	0.7305	1.4119	0.8808	1.2700
13.	1.4933	0.8662	1.7571	1.0699	1.5601
14.	1.6485	0.8956	1.9858	1.1227	1.7466
15.	1.7770	0.9256	2.1573	1.1788	1.8884
16.	1.9202	0.9572	2.3750	1.2331	2.0507
17.	2.0806	0.9893	2.6183	1.2900	2.2355
18.	2.2519	1.0226	2.8810	1.3544	2.4312
19.	2.4292	1.0575	3.1468	1.4162	2.6343
20.	2.6208	1.0921	3.4425	1.4815	2.8559
21.	2.8337	1.1274	3.7936	1.5500	3.1090
22.	3.0668	1.1640	2.9828	1.6245	3.3811
23.	3.3602	1.2017	4.4899	1.6996	3.8465
24.	3.7345	1.2407	4.9685	1.7789	5.8491
25.	4.2434	1.2807	5.4544	1.6621	6.1298

PUBLIC SECTOR

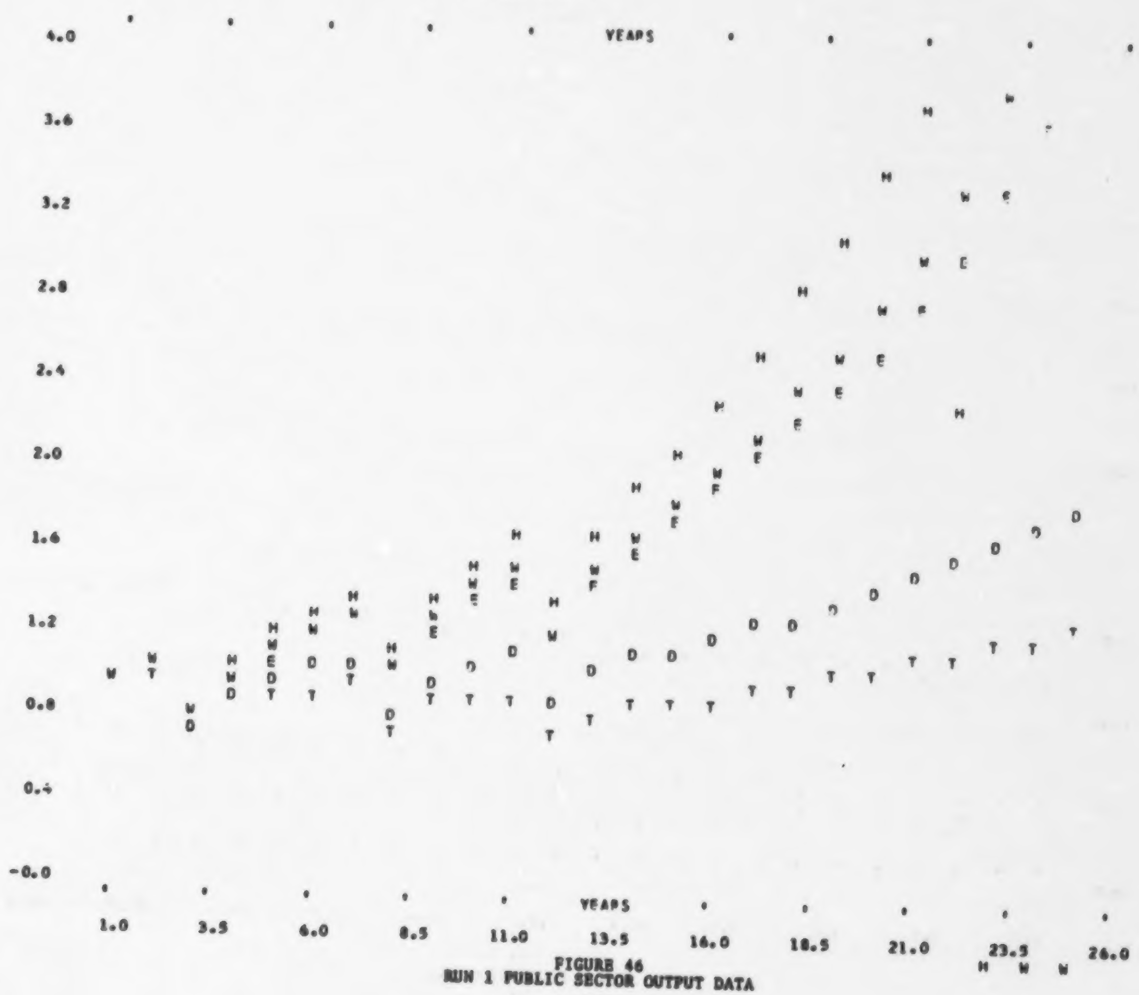


FIGURE 46
RUN 1 PUBLIC SECTOR OUTPUT DATA

TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS
(SCALED TO CRIGINAL VALUE)

YEAR	HEAVY POLL. MANUFACTURE (H)	LIGHT POLL. MANUFACTURE (L)	COMMERCIAL (C)	AGRICULTURE (F)	HOUSEHCLD & RECREATION (R)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0398	1.0454	1.0208	1.0005	1.0358
3.	0.8039	0.8118	0.7486	0.8443	1.0639
4.	0.9403	0.5378	0.8581	0.9202	1.0989
5.	0.9872	0.9814	0.8771	0.9229	1.1323
6.	1.0352	1.0267	0.8964	0.9256	1.1676
7.	1.0752	1.0658	0.9132	0.9263	1.2027
8.	0.8796	0.8810	0.6939	0.7850	1.2400
9.	1.0230	1.0123	0.8143	0.8379	1.2811
10.	1.0689	1.0602	0.8324	0.8407	1.3221
11.	1.1104	1.1042	0.8492	0.8424	1.3635
12.	0.9119	0.9146	0.6504	0.7095	1.4093
13.	1.0658	1.0538	0.7636	0.7740	1.4640
14.	1.1103	1.1022	0.7809	0.7767	1.5160
15.	1.1591	1.1520	0.7986	0.7790	1.5720
16.	1.2339	1.2426	0.8169	0.7814	1.6321
17.	1.2802	1.2874	0.8369	0.7836	1.6922
18.	1.3405	1.3452	0.8559	0.7862	1.7539
19.	1.3952	1.4007	0.8753	0.7886	1.8210
20.	1.4524	1.4578	0.8958	0.7907	1.8879
21.	1.5111	1.5168	0.9153	0.7709	1.8096
22.	1.0064	1.5818	0.8996	0.6989	1.4671
23.	1.6765	1.5663	0.5840	0.7102	1.4043
24.	1.7400	1.6719	1.0342	0.7538	1.5241
25.	1.8318	1.7103	1.0827	0.7861	1.5835

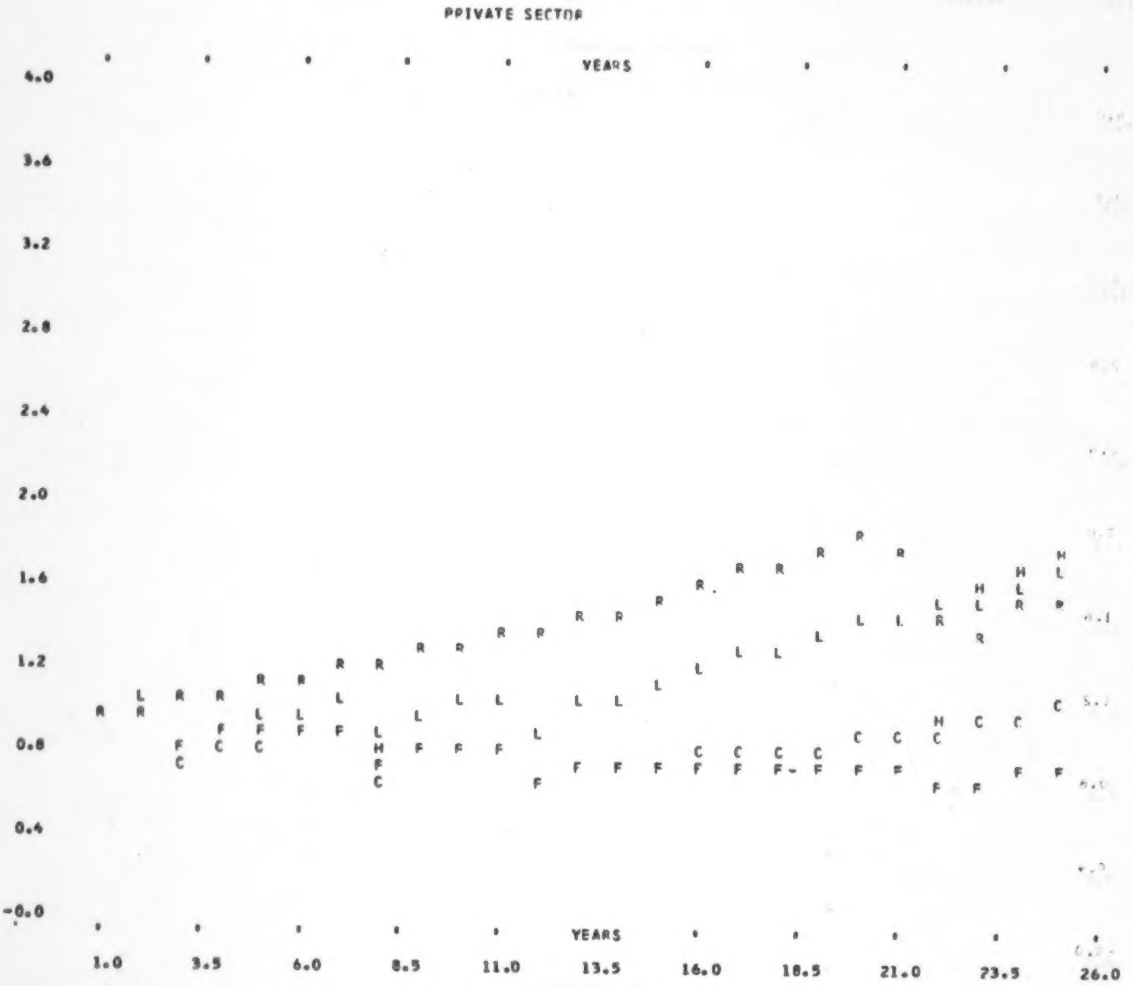


FIGURE 47
RUN 1 PRIVATE SECTOR OUTPUT DATA

TABLE NUMBER FOUR - NATURAL RESOURCES USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	IRON (I)	COPPER (C)	LEAD AND ZINC (L)	MERCURY (M)	SILVER (S)	TRACE ORES (T)
1.	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0358	1.0404	1.0419	1.0514	1.0633	1.0541
3.	0.8048	0.8047	0.8077	0.8267	0.7614	0.9759
4.	0.9685	0.9036	0.9462	0.6065	0.4671	1.8081
5.	1.2341	0.7249	0.9958	0.6465	0.5093	1.9434
6.	1.2883	0.7600	1.0420	0.5165	0.3197	2.3754
7.	1.4372	0.6862	1.0835	0.4713	0.2432	2.6308
8.	1.2086	0.5279	0.6797	0.4084	0.1984	2.2361
9.	1.3984	0.6132	1.0285	0.4676	0.2388	2.6054
10.	1.4570	0.6408	1.0830	0.5005	0.2611	2.8148
11.	1.5105	0.6659	1.1282	0.5245	0.2763	2.9607
12.	1.2386	0.5473	0.9207	0.4567	0.2272	2.5317
13.	1.4413	0.6302	1.0942	0.5285	0.2762	3.0362
14.	1.4985	0.6399	1.1712	0.5676	0.3030	3.3963
15.	1.5604	0.6399	1.2580	0.6007	0.3244	3.7849
16.	1.6558	0.6410	1.3832	0.6449	0.3526	4.3331
17.	1.7146	0.6149	1.5021	0.6863	0.3810	4.9378
18.	1.7901	0.5912	1.6384	0.7323	0.4125	5.6055
19.	1.8596	0.5688	1.7671	0.7785	0.4438	6.2467
20.	1.9319	0.5568	1.8909	0.8286	0.4784	6.8604
21.	2.0039	0.5563	2.0081	0.8731	0.5186	7.4078
22.	1.4746	0.3830	1.5227	0.6383	0.3368	5.2290
23.	2.1875	0.5556	2.2344	0.9392	0.6026	8.2855
24.	2.2779	0.6239	2.3582	1.0219	0.6564	8.9141
25.	2.3878	0.6551	2.4944	1.0573	0.7130	9.5540

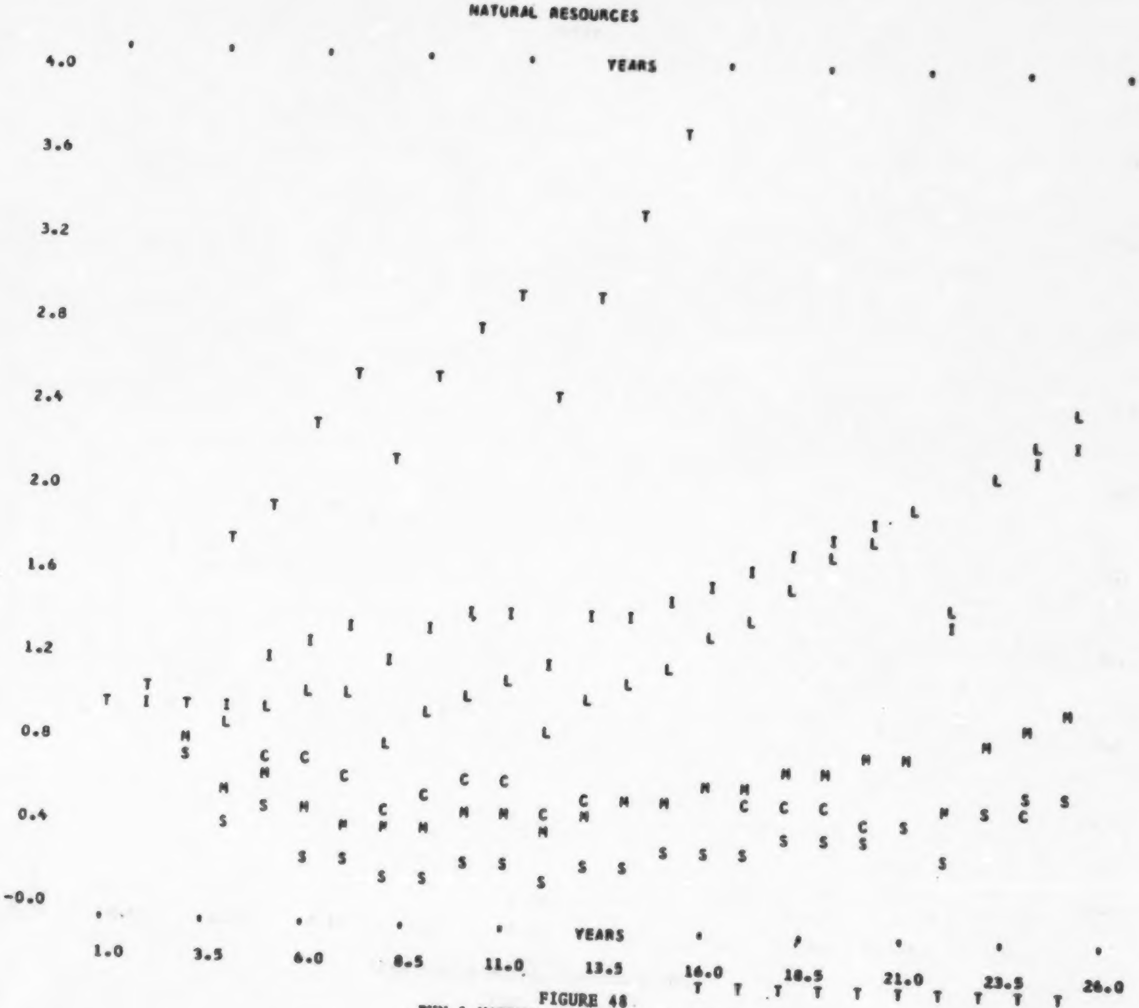


FIGURE 48
RUN 1 NATURAL RESOURCES USE DATA

TABLE NUMBER FIVE - ENERGY & AGRICULTURAL USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	COAL (C)	OIL (O)	ELECTRICITY (E)	TIMBER (T)	FOOD (F)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0425	1.0388	1.0339	1.0372	1.0287
3.	0.8306	0.8315	0.8341	0.9568	1.0200
4.	0.9592	0.9517	0.9826	1.0265	1.0631
5.	1.0082	0.9949	1.0452	1.0615	1.0904
6.	1.0562	1.0370	1.1079	1.0982	1.1192
7.	1.0981	1.0744	1.1616	1.1327	1.1475
8.	1.0019	0.7139	0.9545	1.0777	1.1490
9.	1.2590	0.6148	1.1238	1.1538	1.1925
10.	1.3249	0.6452	1.2040	1.1946	1.2259
11.	1.3838	0.6725	1.2728	1.2343	1.2593
12.	1.2264	0.5623	1.0298	1.1850	1.2693
13.	1.5955	0.6508	1.1610	1.2709	1.3260
14.	1.9540	0.6867	1.1579	1.3183	1.3681
15.	2.4383	0.7188	1.0902	1.3687	1.4134
16.	3.0770	0.7604	0.9924	1.4337	1.4620
17.	3.9128	0.7979	0.8222	1.4692	1.5105
18.	4.5929	0.8395	0.7211	1.5415	1.5604
19.	5.2070	0.8815	0.6454	1.6003	1.6145
20.	5.8625	0.9262	0.5666	1.6597	1.6685
21.	6.3031	0.9651	0.5641	1.6323	1.6019
22.	5.4605	0.[illegible]0	0.4989	1.4448	1.3135
23.	7.0740	1.[illegible]3	0.6647	1.4135	1.2655
24.	8.5725	1.1891	0.6641	1.5264	1.3700
25.	9.3719	1.1864	0.9588	1.5846	1.4240

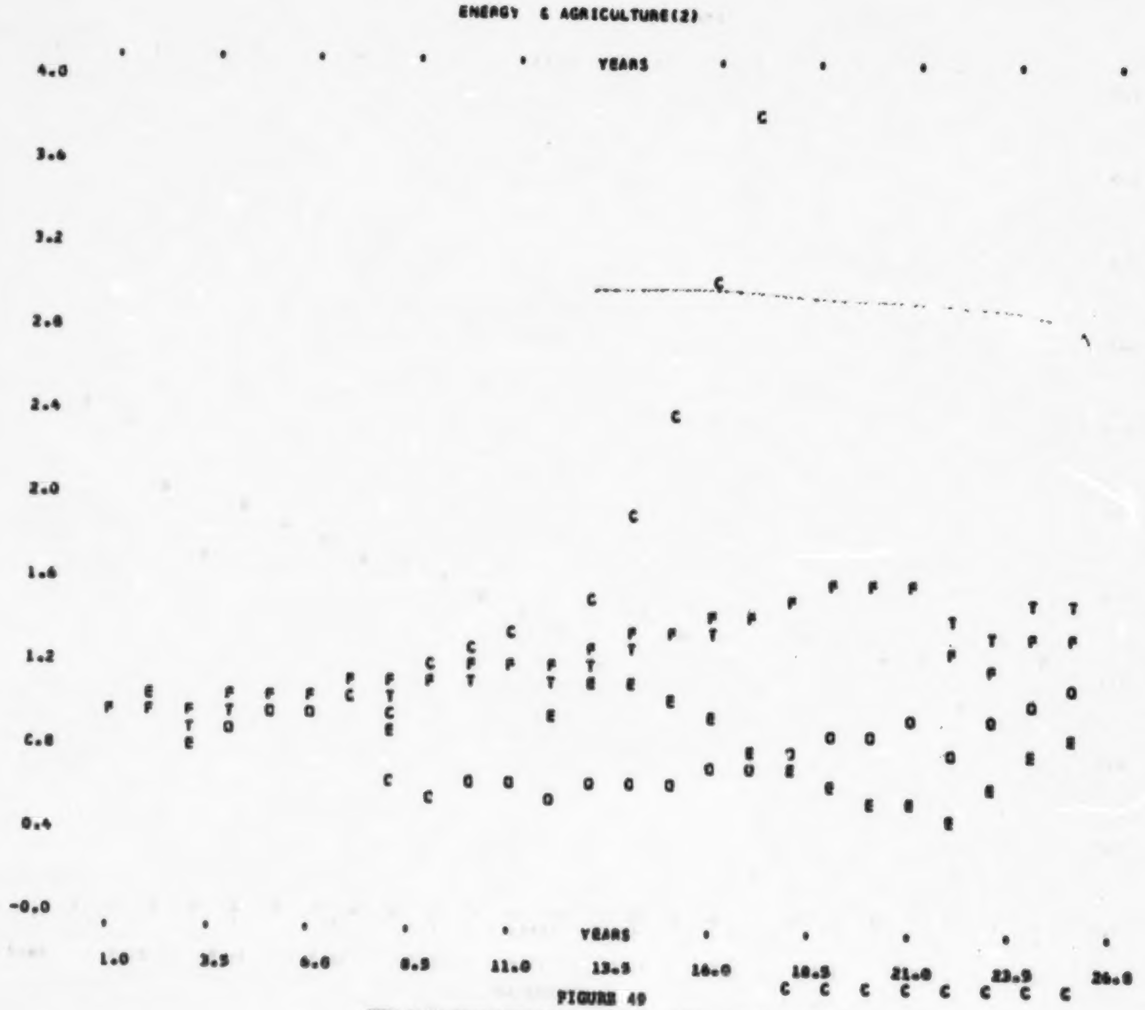


FIGURE 49
RUN 1 ENERGY AND AGRICULTURAL PRODUCTS USE DATA

TABLE NUMBER SIX
UNEMPLJYMENT AND QOL VALUES

YEAR	UNEMPLOYMENT (U)	QUALITY (Q)
1.	0.0681	1.3487
2.	0.0355	1.3905
3.	0.2789	1.1189
4.	0.0800	1.2957
5.	0.0768	1.3377
6.	0.0415	1.3877
7.	0.0169	1.4227
8.	0.2427	1.1798
9.	0.0431	1.3680
10.	0.0348	1.4199
11.	0.0010	1.4671
12.	0.2207	1.2222
13.	0.0010	1.4296
14.	0.0010	1.4910
15.	0.0010	1.5445
16.	0.0010	1.6129
17.	0.0010	1.6815
18.	0.0010	1.7551
19.	0.0010	1.8288
20.	0.0010	1.9066
21.	0.0010	1.5668
22.	0.0010	1.7580
23.	0.0010	2.0458
24.	0.0010	2.3365
25.	0.0010	2.4555

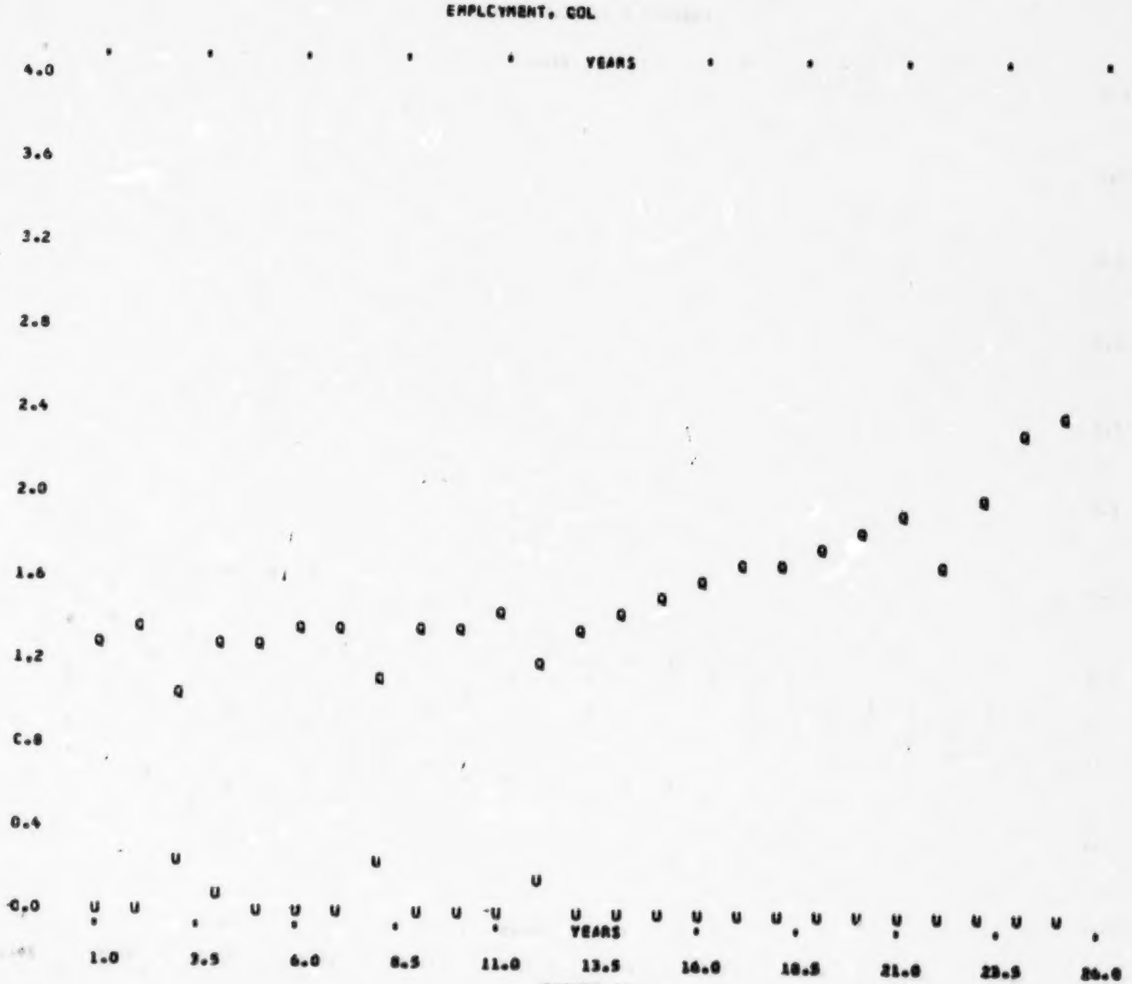


FIGURE 50
RUN 1 UNEMPLOYMENT AND QOL VALUES

TABLE NUMBER SEVEN - LAND, AIR AND WATER USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	URBAN (U)	SUBURBAN (S)	ARABLE (F)	TREATED UNITS OF MEDIA (A)	(W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0335	1.0354	1.0005	1.0453	1.0318
3.	0.9623	0.9512	0.8443	0.8001	0.8576
4.	1.0236	1.0210	0.9202	0.9350	0.9647
5.	1.0546	1.0550	0.9229	0.9818	0.9974
6.	1.0871	1.0905	0.9256	1.0300	1.0313
7.	1.1194	1.1243	0.9263	1.0746	1.0611
8.	1.0690	1.0638	0.7850	0.8717	0.9182
9.	1.1411	1.1421	0.8379	1.0241	1.0193
10.	1.1772	1.1809	0.8407	1.0725	1.0556
11.	1.2135	1.2191	0.8424	1.1190	1.0895
12.	1.0567	1.2654	0.7095	0.9235	0.9512
13.	1.1280	1.3591	0.7740	1.0820	1.0662
14.	1.1668	1.4075	0.7767	1.1319	1.1057
15.	1.2082	1.4600	0.7790	1.1854	1.1475
16.	1.1272	1.6274	0.7814	1.2536	1.2074
17.	1.1672	1.6857	0.7836	1.3078	1.2485
18.	1.2082	1.7479	0.7862	1.3700	1.2965
19.	1.1272	1.9190	0.7886	1.4316	1.3444
20.	1.1670	1.9886	0.7907	1.4942	1.3931
21.	1.1363	1.9492	0.7709	1.5217	1.3870
22.	0.9744	1.6511	0.6989	1.2020	1.1877
23.	0.9569	1.6856	0.7102	1.5402	1.2732
24.	1.0255	1.8048	0.7538	1.6214	1.3740
25.	1.0648	1.8746	0.7861	1.7021	1.4340

LAND(3), AIR AND WATER

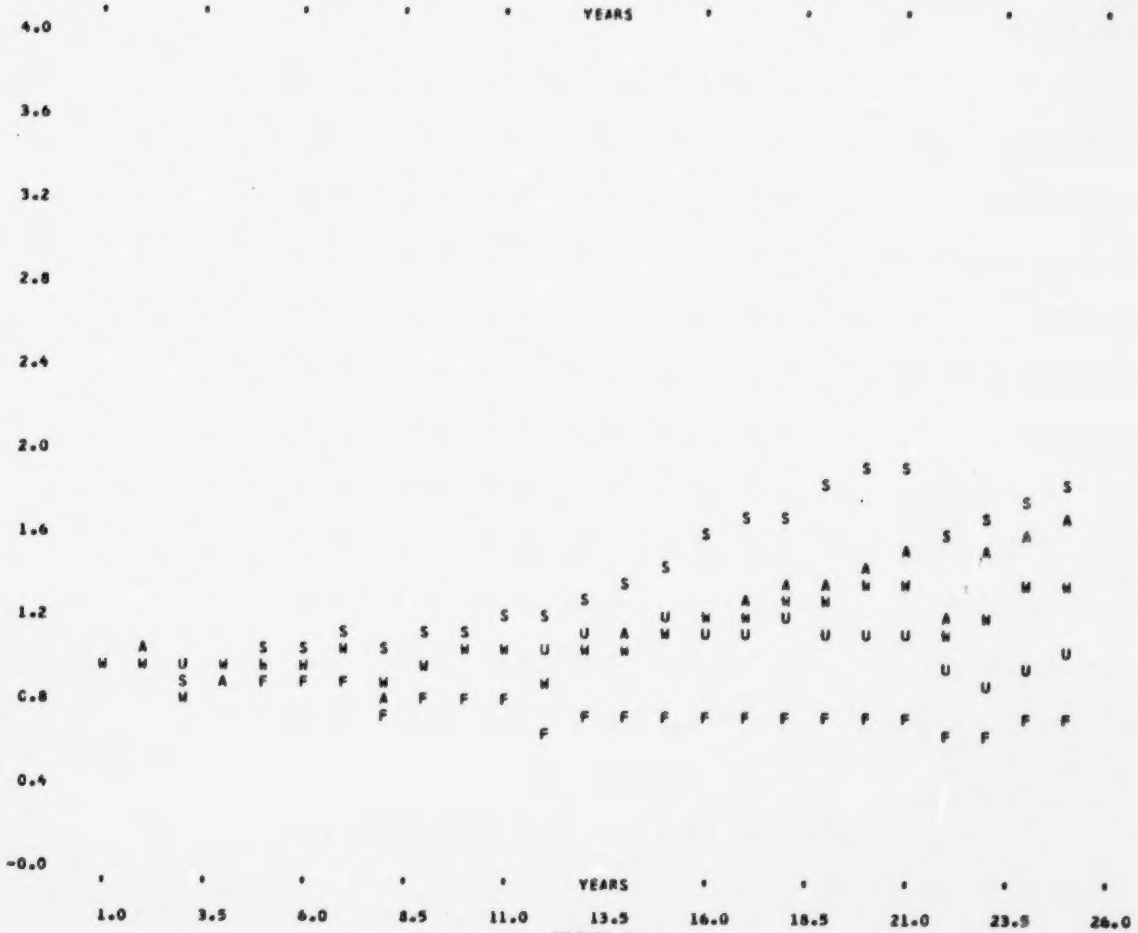


FIGURE 51
RUN 1 LAND, AIR AND WATER USE DATA

- Useful data base variants to be checked parametrically include:
    - reduction of initial economic output by reducing availability of input funds
    - reduction of demand levels - both total consumer levels and per capita thresholds.

The first variation is analyzed next, the second is considered in appendixes of this report.

PARAMETRIC VARIATION OF INVESTMENT GROWTH RATES

In order to reduce stress on the region, several data changes could be made. For the next analysis, the growth of production was reduced by altering the annual growth rate of funds available for maintenance and production. As a first analysis, five runs in addition to the Base Case were done with identical data except the funds growth rates. Figure 53 lists the level of funds used for each variation.

	Annual Fund Growth Rate (in %)					
Component/Run	1	2	3	4	5	6
Education	8.2	5.0	4.0	2.0	0.0	-2.0
Transportation	3.4	3.4	4.0	2.0	0.0	-2.0
Health	9.9	5.0	4.0	2.0	0.0	-2.0
Defense & Other	5.0	5.0	4.0	2.0	0.0	-2.0
Welfare	8.8	5.0	4.0	2.0	0.0	-2.0
Hvy. Polluting Ind.	4.7	4.7	4.0	2.0	0.0	-2.0
Lgt. Polluting Ind.	4.6	4.6	4.0	2.0	0.0	-2.0
Commercial	2.2	2.2	4.0	2.0	0.0	-2.0
Agricultural	0.3	0.3	4.0	2.0	0.0	-2.0
Household & Rec.	3.8	3.8	4.0	2.0	0.0	-2.0

FIGURE 53

VARIATION OF INITIAL DATA FOR RUNS 1-6

Thus, Run 2 varied from Run 1, the Base Case, only by reducing the rapid growth of education, health and welfare funds of the past twenty years to a level still in excess of any level noted in components of the private sector. Runs 3 through 6 provide growth rates for all components that are constant within each run; as such, in Run 3, the components of the private sector actually have more funds growth than in Run 1 while all other sectors for all other runs have reduced funds, thus predicting reduced rates of resource usage.

The question arises; what statistics from a run of the model provide an appropriate comparative measure of regional quality over the 25 years? For this analysis the effectiveness measure was taken as having three elements:

- no resource should be depleted, or have an appearance of imminent, long-term depletion
- satisfaction of demands and levels of production should be reasonably smooth over the entire run
- population growth and demand satisfaction for all 11 measures should be maximized and growing with relative consistancy.

Figure 54 addresses the third of these factors by listing the final values of population size, the final year value of the combined QOL demand satisfaction measure, plus the number of measures that were not satisfied in year 25 or whose thresholds were lowered during the run. Also listed is the need for long term funds redistribution during the run.

	1	2	3	4	5	6
Population Size	1.314	1.295	1.297	1.279	1.143	.998
Combined QOL	1.820	.977	1.096	1.110	.865	.601
Deficient Measures	5	4	7	2	4	11
Reset Funds	Y	N	N	N	N	N

FIGURE 54

COMPARISON OF POPULATION FACTORS, RUNS 1-6

As an initial analysis, the following elements are noted. Run 1 does support the greatest population with the highest combined QOL level of all of the runs; however, as was noted in the analysis above for the run the QOL values do not have an internally consistant trend and major resource deficiencies exist.

The comparative values of the QOL measures in Runs 1 and 2 had a different cause; in Run 1 it had been noted that the growth in values was quite divergent among the measures due to the level of funds available to the components of HEW. When the growth of HEW were effectively reduced 40% for Run 2, the combined QOL value was significantly reduced, never growing above 1.10 of the original value. Hence, Run 2 must be rated as inferior to Run 1 and highlights the primary problems of Run 1, imbalance of the measures plus significant depletion of scarce resources (food, silver, fuels).

Runs 3 and 4 appear the smoothest in terms of population and QOL growth plus maintenance of demand thresholds without a major funds adjustment. Run 4 supported a population smaller than Run 3 by 1.5% at a 2.0% higher QOL and at a much lower funds growth level (2% vis-a-vis 4%) and while maintaining high, consistant satisfaction of per capita demands (9 satisfied compared to 4).

The output of Run 5 (0.0 funds growth) and Run 6 (reduction of funds) clearly indicate that stagnation in economic growth while allowing population growth to continue provides a much reduced QOL satisfaction level and, for SOS-1, resulted in high unemployment and out-migration.

A second analysis of these six runs concerns the avialability of resources. This comparison is not quite the straightforward trend that might be expected. Increased resource usage in some cases caused a price rise, thus stimulating in SOS-1 adjustments expanded economically available stockpiles. Figure 55 provides the remaining stockpiles for year 25 for the eight nonrenewable resources.

	1	2	3	4	5	6
Iron	12900.	6700.	7300.	12100.	14000.	13200.
Copper	17100.	17900.	17000.	16900.	14100.	14600.
Lead, Zinc	13600.	3800.	8900.	4200.	20100.	20200.
Mercury	1400.	4900.	4900.	5100.	4200.	5300.
Silver	0.	800.	1200.	1000.	1000.	900.
Trace Metal	12600.	20400.	21000.	18742.	13700.	15300.
Coal	5800.	7400.	7700.	7600.	8600.	7200.
Oil	4800.	5000.	9800.	4900.	6200.	17900.

FIGURE 55

REMAINING STOCKPILES AT t=25, RUNS 1-6

The unit cost mechanism for expanding stockpiles and perserving stocks of critical resources by substitution appears quite effective except for Run 1, silver and mercury. To choose a best usage run among Runs 3-6 is hazardous. Run 2 appears consistantly lower in reserves than the other 4 runs but has no emergency situation in the durable ores. Hence, based on this statistic any run among 2-6 appears quite acceptable.

In the other resources, Runs 1 and 2 as discussed earlier had a severe shortage in food. Both also had high salary rate growth and extended work weeks in year 25. Run 3 had a salary increase over 25 years of 50% while Run 4 experienced a 10% increase. In terms of steady low unemployment Run 4 is the smoothest; Run 3 in five years had unemployment over 10% while Runs 5 and 6 have steadily increasing unemployment to high values as production dropped. For Run 4 the employment spread is 4.5%-9.0% except for two years.

Based on the resource utilization and availability statistics Run 4 is appears best followed by Run 3. Run 1 is unacceptable and Run 2 suggests growing problem areas.

The final criterion of goodness is smoothness of trends. Figure 44 is the summary data for Run 1; Figures 56-60 provide the same for the other runs. Runs 1-3 provide rather ragged

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0491	1.0371	1.0187	1.0373	1.0346	1.0270	1.0381	1.0308
3.	1.0324	1.0915	1.0670	0.9015	0.9157	0.9164	0.9892	0.8959	0.9417
4.	1.0376	1.1142	1.0884	0.9777	0.9852	0.9992	1.0364	0.9921	1.0086
5.	1.0478	1.1715	1.1258	0.9947	1.0278	1.0369	1.0629	1.0315	1.0418
6.	1.0582	1.2356	1.1792	1.0235	1.0825	1.0893	1.0940	1.0769	1.0869
7.	1.0697	1.3073	1.2126	1.0374	1.1033	1.1170	1.1190	1.1158	1.1127
8.	1.0817	1.3619	1.2533	1.0041	1.0826	1.0568	1.1239	1.0815	1.0984
9.	1.0917	1.4306	1.2974	1.0556	1.1635	1.0906	1.1634	1.1632	1.1586
10.	1.1048	1.4935	1.3365	0.8908	0.9759	0.9172	1.1077	0.9445	1.0257
11.	1.1084	1.5299	1.3736	1.0015	1.1063	1.0345	1.1729	1.0878	1.1250
12.	1.1195	1.6074	1.4185	1.0179	1.1574	1.0722	1.2053	1.1316	1.1591
13.	1.1305	1.7372	1.4977	1.0593	1.2596	1.1365	1.2484	1.1960	1.2162
14.	1.1436	1.8110	1.5468	1.0740	1.3270	1.1686	1.2802	1.2363	1.2502
15.	1.1576	1.8938	1.6033	1.0067	1.2984	1.1190	1.2766	1.1462	1.2026
16.	1.1678	1.9841	1.6453	1.0794	1.4600	1.2429	1.3339	1.2585	1.2774
17.	1.1830	2.0958	1.7368	0.8908	1.2573	1.0703	1.2764	0.9786	1.1170
18.	1.1867	2.1613	1.7895	1.0276	1.5048	1.3055	1.3617	1.1639	1.2504
19.	1.2011	2.2762	1.8513	1.0471	1.6079	1.4498	1.4033	1.2144	1.2933
20.	1.2151	2.4419	1.9269	1.0799	1.7109	1.6431	1.4502	1.2773	1.3430
21.	1.2308	2.5626	2.0268	1.0837	1.8081	1.7723	1.3945	1.3334	1.3573
22.	1.2468	2.6780	2.0830	1.0420	1.8399	1.8351	1.2114	1.3801	1.2980
23.	1.2629	2.8002	2.1702	1.0488	1.9167	1.9406	1.2369	1.4349	1.3381
24.	1.2786	2.9415	2.2612	1.0518	1.9880	2.0177	1.1840	1.4940	1.3440
25.	1.2952	3.0834	2.3554	0.9771	2.0159	1.9987	0.8581	1.5431	1.2215

STATE OF THE SYSTEM

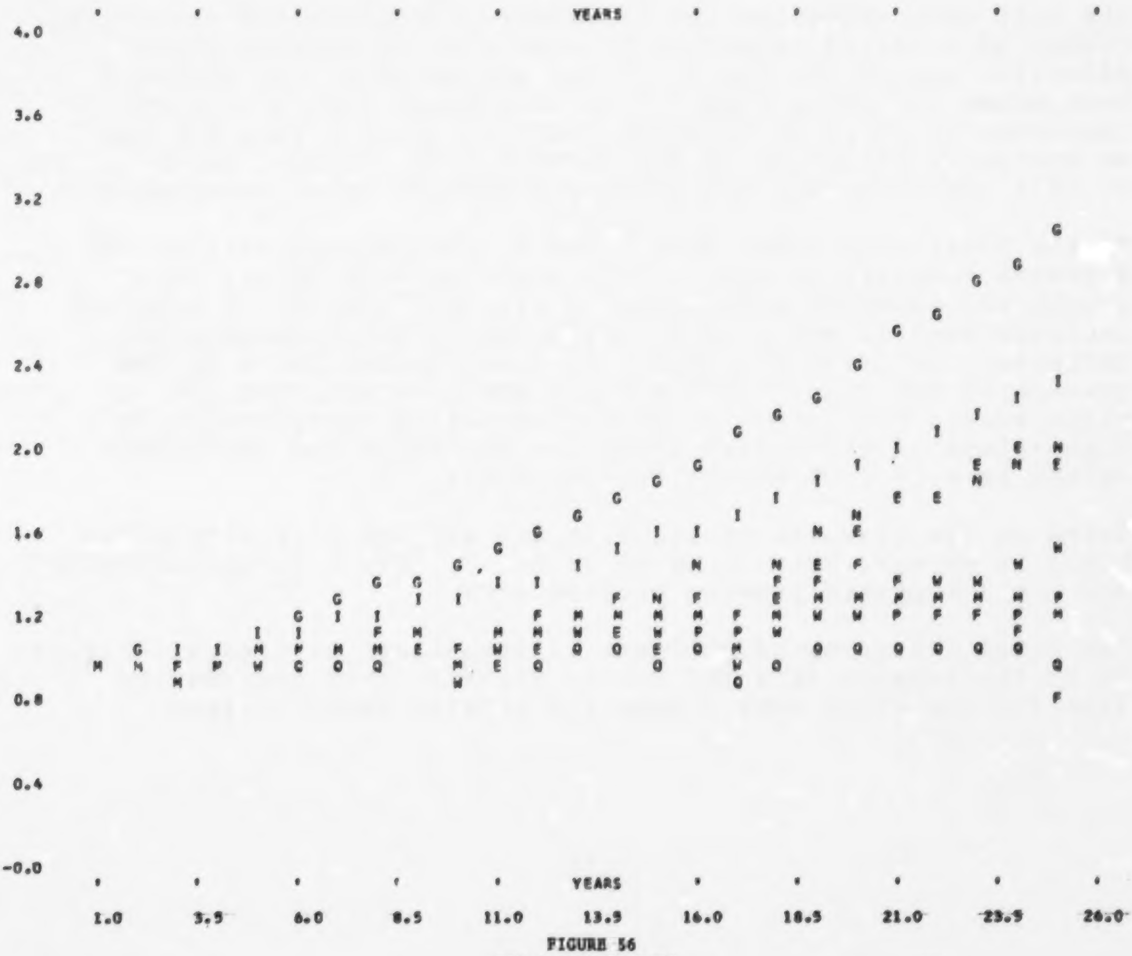


FIGURE 56
RUN 2 SUMMARY DATA

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (W)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0400	1.0400	1.0259	1.0345	1.0370	1.0379	1.0388	1.0368
3.	1.0324	1.0742	1.0721	0.9077	0.9057	0.9142	1.0040	0.8899	0.9468
4.	1.0374	1.0885	1.0943	0.9909	0.9732	0.9996	1.0600	0.9880	1.0187
5.	1.0475	1.1323	1.1369	1.0189	1.0140	1.0415	1.1021	1.0291	1.0615
6.	1.0580	1.1779	1.1767	1.0436	1.0444	1.0805	1.1379	1.0687	1.0988
7.	1.0692	1.2295	1.2352	1.0790	1.0957	1.0971	1.1815	1.1179	1.1477
8.	1.0816	1.2747	1.2726	0.9669	0.9743	0.9460	1.1545	0.9761	1.0675
9.	1.0876	1.3136	1.3037	1.0565	1.0672	1.0347	1.2185	1.0851	1.1486
10.	1.0990	1.3730	1.3700	1.0923	1.1242	1.0875	1.2679	1.1349	1.2071
11.	1.1108	1.4336	1.4185	1.1253	1.1681	1.1356	1.3147	1.1923	1.2558
12.	1.1240	1.4834	1.4675	1.0595	1.1054	1.0717	1.3098	1.1069	1.2129
13.	1.1332	1.5398	1.5280	1.1357	1.2259	1.1590	1.3813	1.2080	1.3058
14.	1.1472	1.6111	1.5665	1.0228	1.1201	1.0407	1.3569	1.0497	1.2051
15.	1.1541	1.6603	1.6289	1.1227	1.2731	1.1420	1.4368	1.1727	1.3012
16.	1.1678	1.7447	1.7185	1.1703	1.4033	1.2133	1.5090	1.2436	1.3799
17.	1.1830	1.8148	1.7824	0.9954	1.2175	1.0384	1.4454	1.0056	1.2256
18.	1.1881	1.8782	1.8356	1.1309	1.4286	1.2109	1.5470	1.1619	1.3521
19.	1.2027	1.9541	1.9336	1.1605	1.5383	1.3227	1.6163	1.2114	1.4207
20.	1.2172	2.0307	2.0060	1.1934	1.6249	1.4547	1.6753	1.2609	1.4749
21.	1.2330	2.1334	2.0868	1.2365	1.7012	1.6534	1.7486	1.3324	1.5447
22.	1.2490	2.2182	2.1651	1.2649	1.7637	1.8058	1.8083	1.3835	1.5993
23.	1.2651	2.2981	2.2451	1.2841	1.8028	1.9346	1.8399	1.4297	1.6352
24.	1.2815	2.4245	2.3384	1.0355	1.1819	1.9755	1.0437	1.3053	1.0184
25.	1.2970	2.5025	2.4171	1.0964	1.4654	1.8422	1.3303	1.4164	1.2682

STATE OF THE SYSTEM

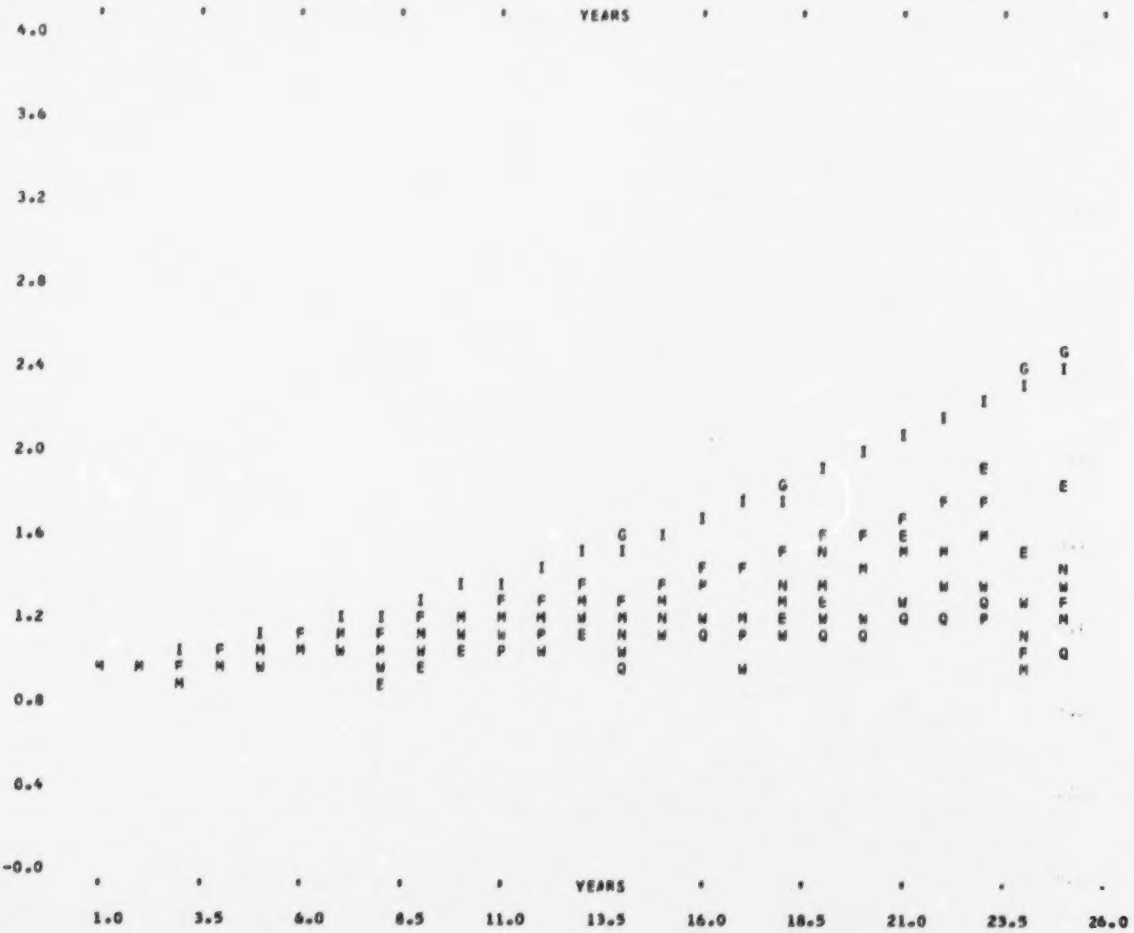


FIGURE 57
RUN 3 SUMMARY DATA

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (C)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0200	1.0200	1.0061	1.0146	1.0170	1.0179	1.0189	1.0169
3.	1.0317	1.0368	1.0360	1.0083	1.0210	1.0300	1.0321	1.0343	1.0300
4.	1.0423	1.0547	1.0536	1.0145	1.0201	1.0481	1.0498	1.0521	1.0482
5.	1.0531	1.0724	1.0702	1.0188	1.0353	1.0643	1.0662	1.0694	1.0653
6.	1.0640	1.0909	1.0853	1.0199	1.0424	1.0755	1.0785	1.0859	1.0793
7.	1.0748	1.1095	1.1034	1.0261	1.0549	1.0602	1.0968	1.1042	1.0976
8.	1.0856	1.1287	1.1215	1.0324	1.0713	1.0401	1.1147	1.1230	1.1159
9.	1.0964	1.1482	1.1399	1.0390	1.0675	1.0569	1.1331	1.1420	1.1344
10.	1.1072	1.1682	1.1588	1.0456	1.1030	1.0732	1.1513	1.1611	1.1523
11.	1.1181	1.1886	1.1783	1.0514	1.1190	1.0900	1.1700	1.1805	1.1708
12.	1.1290	1.2094	1.1981	1.0575	1.1449	1.1070	1.1890	1.2003	1.1896
13.	1.1401	1.2341	1.2217	1.0669	1.1629	1.1270	1.2089	1.2235	1.2114
14.	1.1517	1.2580	1.2440	1.0741	1.2313	1.1454	1.2257	1.2453	1.2315
15.	1.1638	1.2832	1.2683	1.0824	1.2951	1.1657	1.2524	1.2684	1.2534
16.	1.1764	1.3082	1.2924	1.0899	1.3661	1.2028	1.2751	1.2910	1.2751
17.	1.1895	1.3342	1.3168	0.9420	1.2215	1.0632	1.2131	1.0711	1.1391
18.	1.1942	1.3294	1.3310	1.0287	1.3748	1.2080	1.2712	1.1847	1.2199
19.	1.2050	1.3599	1.3579	1.0412	1.4336	1.3055	1.3018	1.2120	1.2478
20.	1.2155	1.3910	1.3850	1.0545	1.4866	1.4187	1.3271	1.2395	1.2733
21.	1.2267	1.4268	1.4127	1.0708	1.5364	1.5423	1.3510	1.2693	1.3003
22.	1.2387	1.4573	1.4605	1.0865	1.5970	1.7016	1.3825	1.3006	1.3412
23.	1.2515	1.4896	1.4846	1.0966	1.6238	1.7842	1.4082	1.3278	1.3642
24.	1.2647	1.5194	1.5139	1.1062	1.6539	1.8499	1.4356	1.3540	1.3904
25.	1.2785	1.5756	1.5424	1.1179	1.6824	1.9032	1.4623	1.3859	1.4156

STATE OF THE SYSTEM

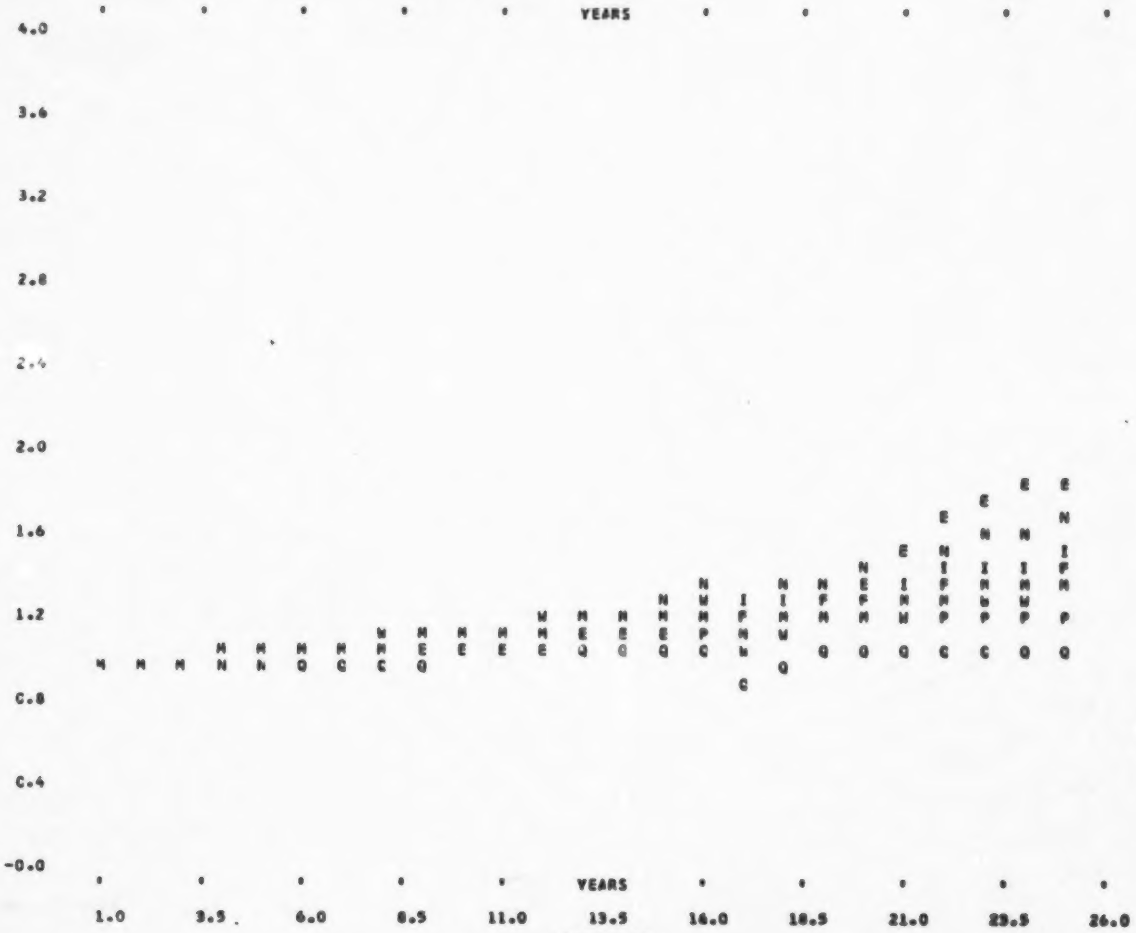


FIGURE 58
RUN 4 SUMMARY DATA

SUMMARY TABLE - STATE OF THF SYSTEM
(SCALED TO OPIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0030	1.0000	0.9864	0.9947	0.9971	0.9979	0.9989	0.9970
3.	1.0309	1.0000	1.0000	0.9744	0.9864	0.9945	0.9967	0.9980	0.9941
4.	1.0401	0.9954	0.9979	0.9595	0.9688	0.9894	0.9953	0.9901	0.9950
5.	1.0486	0.9954	0.9840	0.9475	0.9532	0.9803	0.9918	0.9877	0.9836
6.	1.0564	0.9954	0.9840	0.9405	0.9467	0.9808	0.9918	0.9878	0.9841
7.	1.0639	0.9954	0.9840	0.9328	0.9428	0.9800	0.9911	0.9873	0.9832
8.	1.0708	0.9954	0.9840	0.9263	0.9419	0.9464	0.9907	0.9870	0.9825
9.	1.0771	1.0000	0.9861	0.9281	C.9440	0.9207	0.9937	0.9959	0.9834
10.	1.0832	1.0000	0.9861	0.9231	0.9441	0.9210	0.9940	0.9962	0.9837
11.	1.0888	1.0000	0.9861	0.9175	0.9432	0.9206	0.9939	0.9960	0.9832
12.	1.0939	1.3000	0.9861	0.9128	0.9424	0.9202	0.9937	0.9959	0.9827
13.	1.0987	1.0000	0.9861	0.9085	0.9497	0.9198	0.9936	0.9958	0.9822
14.	1.1033	0.9954	0.9840	0.8982	0.9634	0.9133	0.9912	0.9872	0.9818
15.	1.1075	0.9954	0.9840	0.8950	0.9871	0.9128	0.9909	0.9869	0.9813
16.	1.1116	0.9954	0.9840	0.8913	1.0192	0.9119	0.9903	0.9864	0.9803
17.	1.1155	0.9954	0.9840	0.8879	1.0575	0.9112	0.9899	0.9861	0.9796
18.	1.1193	0.9954	0.9840	0.8846	1.0950	0.9103	0.9895	0.9857	0.9787
19.	1.1230	C.9954	0.9840	0.8812	1.1250	0.9089	0.9890	0.9851	0.9773
20.	1.1265	0.9954	0.9840	0.8784	1.1504	0.9091	0.9886	0.9850	0.9772
21.	1.1299	0.9954	0.9840	0.8757	1.1660	0.9089	0.9884	0.9848	0.9771
22.	1.1332	0.9954	0.9840	0.8728	1.1730	0.9084	0.9880	0.9845	0.9765
23.	1.1364	0.9954	0.9840	0.8701	1.1720	0.9078	0.9876	0.9842	0.9759
24.	1.1395	0.9954	0.5840	0.8674	1.1709	0.9072	0.9872	0.9838	0.9752
25.	1.1425	0.9954	0.9840	0.8649	1.1692	0.9064	0.9868	0.9834	0.9743

STATE OF THE SYSTEM

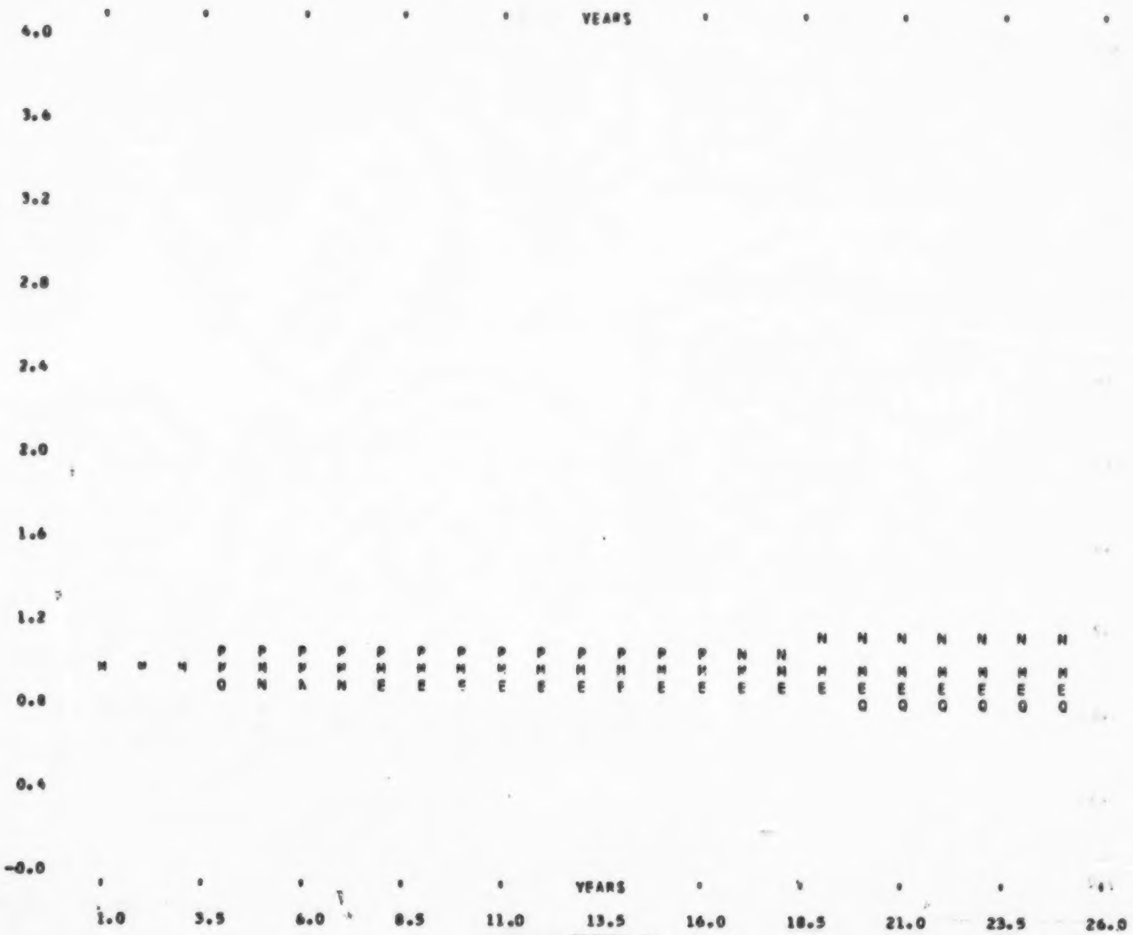


FIGURE 59
RUN 5 SUMMARY DATA

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL OPF USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (H)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	0.9800	0.9800	0.9667	0.9748	0.9771	0.9780	0.9789	0.9779
3.	1.0301	0.9604	C.9604	0.9344	0.9474	0.9552	0.9573	0.9585	0.9548
4.	1.0378	0.9412	0.9278	0.9075	0.8972	0.9283	0.9356	0.9375	0.9251
5.	1.0443	0.9224	0.9093	0.8836	0.8802	0.9101	0.9169	0.9188	0.9072
6.	1.0497	0.9039	0.8911	0.8612	0.8567	0.8925	0.8986	0.9006	0.8895
7.	1.0540	0.8858	0.8733	0.8400	0.8369	0.8744	0.8804	0.8824	0.8715
8.	1.0571	0.8681	0.8558	0.8203	0.8193	0.8277	0.8624	0.8644	0.8535
9.	1.0591	0.8508	0.8387	0.8030	0.8039	0.7838	0.8457	0.8476	0.8372
10.	1.0602	0.8291	0.8219	0.7820	0.7818	0.7626	0.8265	0.8232	0.8129
11.	1.0600	0.8125	0.8055	0.7659	0.7656	0.7471	0.8099	0.8066	0.7964
12.	1.0590	0.7823	0.7894	0.7488	0.7498	0.7313	0.7936	0.7869	0.7801
13.	1.0572	0.7667	0.7736	0.7352	0.7343	0.7164	0.7777	0.7711	0.7642
14.	1.0548	0.7513	0.7581	0.7220	0.7254	0.7019	0.7621	0.7556	0.7487
15.	1.0519	0.7363	0.7429	0.7095	0.7221	0.6877	0.7468	0.7404	0.7334
16.	1.0485	0.7216	0.7281	0.6976	0.7255	0.6738	0.7318	0.7256	0.7186
17.	1.0447	0.7038	0.7038	0.6786	0.7330	0.6540	0.7043	0.7048	0.6995
18.	1.0402	0.6897	0.6897	0.6675	0.7463	0.6408	0.6901	0.6906	0.6855
19.	1.0352	0.6759	0.6760	0.6575	0.7587	0.6279	0.6763	0.6768	0.6717
20.	1.0297	0.6624	0.6624	0.6477	0.7663	0.6153	0.6627	0.6632	0.6582
21.	1.0240	0.6491	0.6492	0.6383	0.7671	0.6029	0.6494	0.6499	0.6450
22.	1.0179	0.6362	0.6362	0.6293	0.7615	0.5907	0.6364	0.6369	0.6319
23.	1.0115	0.6234	0.6220	0.6177	0.7495	0.5772	0.6206	0.6230	0.6166
24.	1.0049	0.6110	0.6096	0.6093	0.7335	0.5653	0.6081	0.6105	0.6039
25.	0.9979	0.5987	0.5974	0.6018	0.7207	0.5546	0.5960	0.5985	0.5924

STATE OF THE SYSTEM

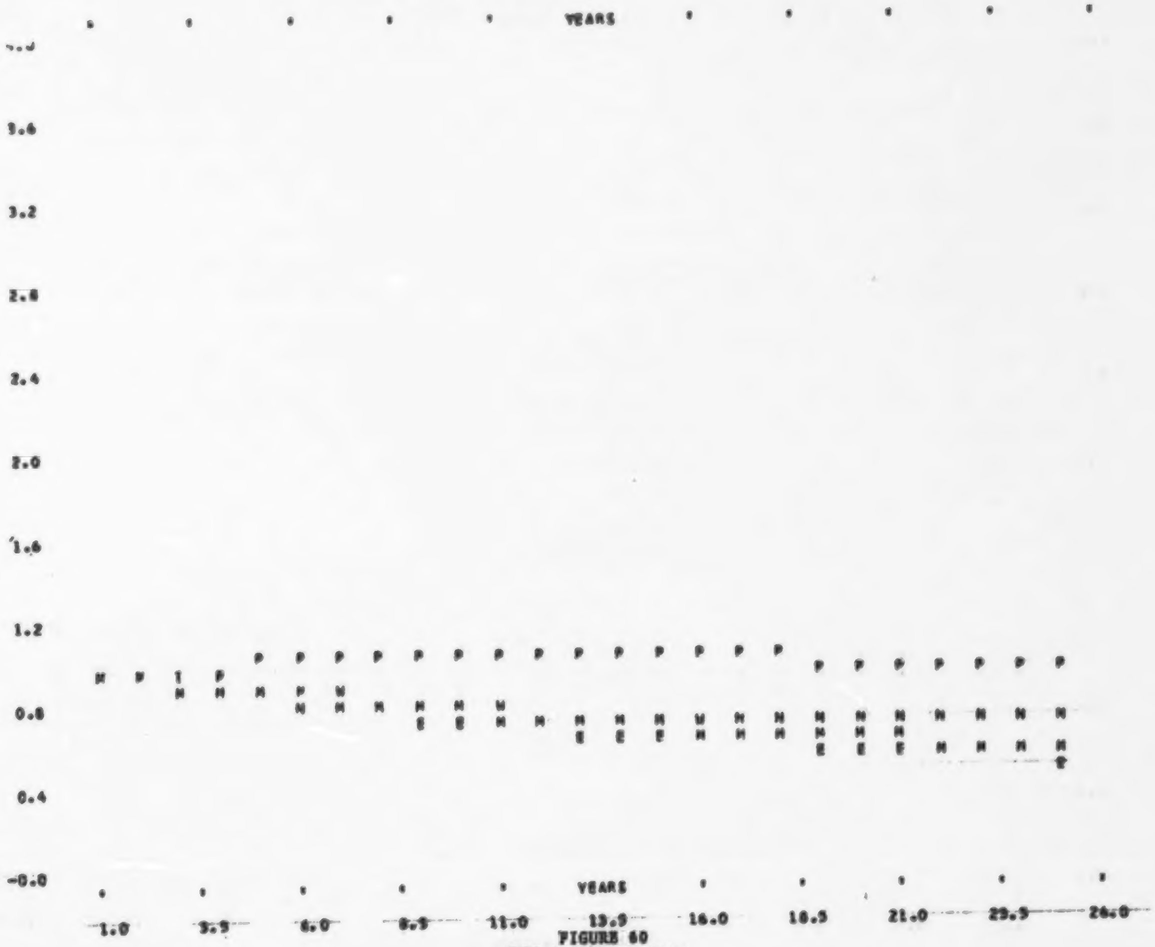


FIGURE 60
RUN 6 SUMMARY DATA

growth patterns while the data points for Runs 4-6 are nearly always fully consistant with the trend lines. However, both Run 5 and 6 show that the region's trend is for an increasingly inferior set of standards. On the other hand Run 4 is a slow, generally increasing set of trends indicating growth within the region's carrying capacity limits.

Review of the comparative analysis above indicates that Run 4 is consistantly the best run while Run 3 is normally the second choice. Hence, based on these data and varying only the funds parameter, the best solution appears to lie between 2-4 percent annual growth, and probably is closer to 2%.

To verify this finding, a seventh run was made to compare to Run 3 and 4 output. The funds levels were set at 3% for components of the government sector and 2% for private components. The results are reasonably consistant with the findings above. Population size approaches Run 4 but QOL is below Run 4. Missed measure thresholds for year 25 are consistant and no long term adjustments were necessary. The remaining nonrenewable resource stockpiles are better than either Run 3 or 4. Unemployment is better than Run 3 but worse than Run 4. Run 7 trends (see Figure 61) are decidedly rougher than Run.4 but not rougher than Run 3.

Additionally, the following trends are noted in Run 7 as compared to Run 4. While productivity in the government sector is slightly higher in the Run 7 data, the productivity of Run 4 in the private sector is clearly higher; ranges are 1.10-1.53 for Run 7 and 1.35-1.49 for Run 4. Thus, for less funds (Run 4) higher overall production was made due to differentials in resource unit costs at year 25. These differences were stimulated by the higher public sector investments. On the other hand, growth in effluent treatment costs over the 25 years is 33% for Run 7 and 51% for Run 4; if it is assumed that effluent treatment is less than 100% effective, the higher level of environmental degradation occurs in Run 4.

Based on this last analysis it appears that the best funds rate is very close to 2.1% if a standard rate is applied to all components and if no variation on levels of population or demand gratification are introduced to the SOS-1 model inputs. Additional discussion in Appendixes 6 and 7 provide consideration of ZPG and Zero Output Demand Growth. The primary findings of these appendixes are that:

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0300	1.0200	1.0100	1.0173	1.0208	1.0185	1.0258	1.0189
3.	1.0319	1.0554	1.0360	1.0147	1.0253	1.0367	1.0333	1.0473	1.0338
4.	1.0431	1.0828	1.0537	1.0234	1.0261	1.0582	1.0516	1.0718	1.0540
5.	1.0546	1.1104	1.0703	0.8910	0.8897	0.9182	1.0017	0.9029	0.9475
6.	1.0589	1.1144	1.0726	0.9611	0.9525	0.9913	1.0399	0.9936	1.0044
7.	1.0680	1.1482	1.0924	0.9699	0.9698	1.0136	1.0582	1.0200	1.0245
8.	1.0767	1.1831	1.1127	0.9835	0.9908	1.0022	1.0773	1.0474	1.0454
9.	1.0859	1.2190	1.1332	0.9982	1.0139	0.9910	1.0976	1.0762	1.0681
10.	1.0954	1.2661	1.1531	1.0192	1.0413	1.0219	1.1202	1.1165	1.0994
11.	1.1058	1.2970	1.1735	1.0260	1.0558	1.0393	1.1387	1.1408	1.1186
12.	1.1164	1.3323	1.1938	1.0366	1.0838	1.0604	1.1583	1.1683	1.1392
13.	1.1275	1.3728	1.2171	1.0501	1.1231	1.0846	1.1790	1.1998	1.1635
14.	1.1394	1.4126	1.2389	1.0610	1.1710	1.1068	1.2004	1.2300	1.1859
15.	1.1521	1.4788	1.2629	1.0696	1.2261	1.1253	1.2203	1.2584	1.2042
16.	1.1654	1.5152	1.2860	0.9667	1.1480	1.0174	1.1847	1.1134	1.1180
17.	1.1730	1.5218	1.3163	1.0365	1.2872	1.0970	1.2351	1.2117	1.1876
18.	1.1856	1.5687	1.3383	1.0449	1.3493	1.1207	1.2580	1.2433	1.2101
19.	1.1982	1.6211	1.3638	1.0618	1.4094	1.1517	1.2859	1.2874	1.2475
20.	1.2119	1.6778	1.3892	1.0752	1.4514	1.1783	1.3072	1.3239	1.2717
21.	1.2266	1.7623	1.4144	0.9386	1.2669	1.0401	1.2489	1.1174	1.1421
22.	1.2331	1.7740	1.4501	1.0315	1.4071	1.1792	1.3127	1.2485	1.2340
23.	1.2468	1.8337	1.4792	1.0444	1.4367	1.2632	1.3445	1.2864	1.2636
24.	1.2603	1.8956	1.5094	1.0601	1.4747	1.3721	1.3721	1.3256	1.2926
25.	1.2748	1.9979	1.5394	1.0837	1.5192	1.5095	1.4042	1.3832	1.3348

STATE OF THE SYSTEM

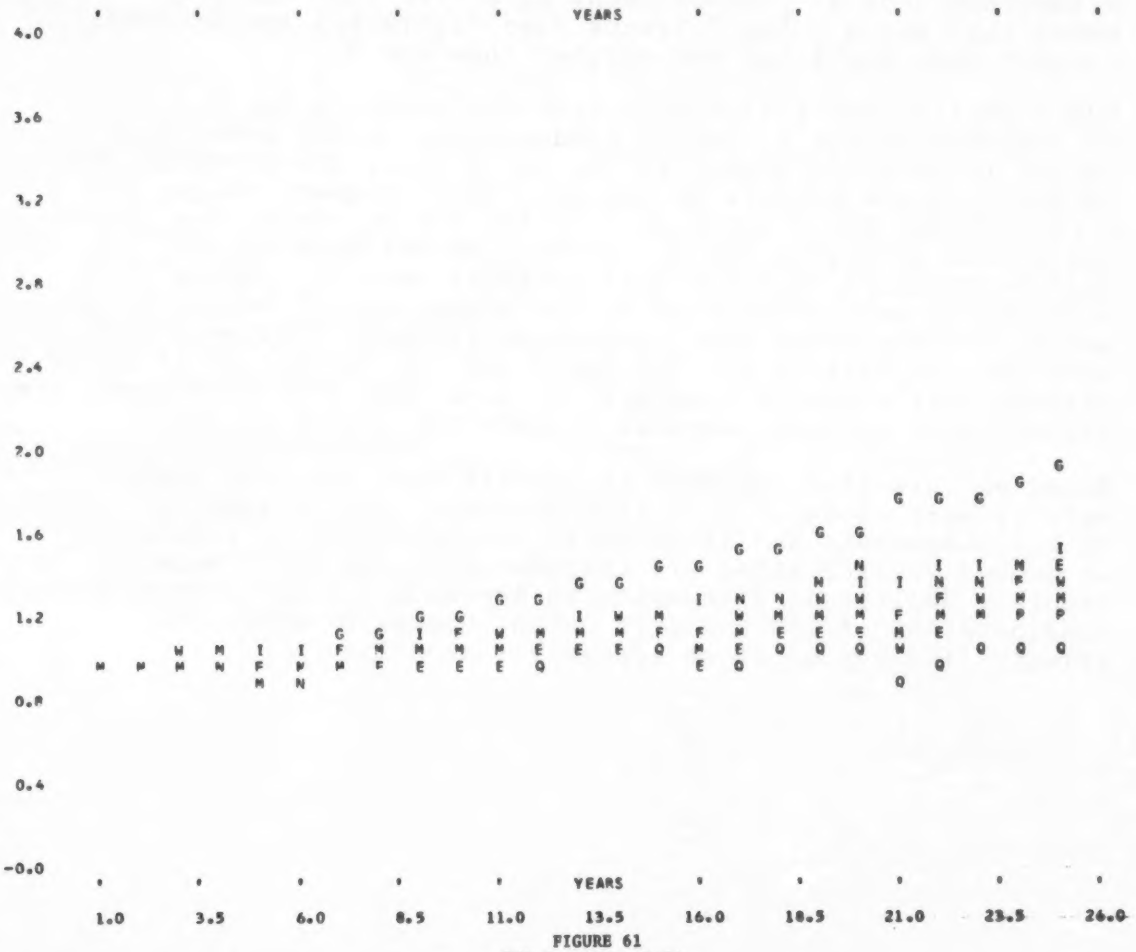


FIGURE 61
RUN 7 SUMMARY DATA

Limiting population but not growth of demand to original limits produces little differences; the lower population raises demand to stress the production system quite similar to the runs discussed above. In a set of comparison runs (Appendix 7) the ZPG case normally fared worse than the standard case.

Limiting demand thresholds to the original values produce a more balanced set of trends plus greater fund reserves for needed long term adjustment. In a set of comparative runs (Appendix 6) this flexibility had little long term impact.

FINDINGS AND RECOMMENDATIONS

The model results generally appear credible; anticipated major trends occur and differences between runs appear to be appropriate.

All forms of the system adjustments appear to function properly and to produce changes in resource utilization data that extend the region's capability to sustain the attempted growth and reduce the impact of degradation of the system when the growth pattern cannot be sustained.

While the model results are considered credible because expected adjustment patterns exist, the results are not fully predictable from static analysis nor are the details of the results at all predictable. The model algorithms and adjustment produce detailed results that gave unexpected answers and insights to which problems may occur and the methods used by the system for adjustment.

The major set of problems with the model at this time is a need to refine certain averaging procedures and a mechanical change to extend the sets of options of adjustments. The linear interpolation procedures used in many calculations of Step 2 and the linear extrapolations as applied in Step 7 should be replaced with more exacting calculations in later versions of SOS, as the data base is improved. Additionally, the sets of adjustments, particularly in the resource substitution mixes and the production resource utilization formulas, should be extended to include more choices and more mixed strategies as end points.

The question arises; should the total data base be expanded for SOS applications? Our answer is yes and no; there appear a set of analyses that can be analyzed efficiently and rapidly using SOS at approximately its present level of detail. The results of these rough-grain analyses will produce some results that require more detailed study. These results can be usefully addressed by a form of SOS that included much greater detail in data and specialized algorithms. Suggested development plans for both SOS forms; the quick reaction, aggregate tool (SOS-Q) and the larger, more detailed system (SOS-D) follow.

For SOS-Q, there appears to be little need in expanding the number of demand measures, resources or production components, that are discretely considered. As noted earlier, the primary expansion needed in the data base is expansion of the number of adjustments options allowed. The question of introduction of some new elements into the data set is straight-forward. For resources and for demand measures additional space exists to introduce 3-4 elements while retaining the present elements. Additionally, any of these which appear dominated by other elements can be replaced; this modification requires primarily a change in data and in output print formats.

Primary development should be to improve the current interpolations noted above. Then the model can be used to test out new adjustment or allocation techniques with minor modification of procedures; the modular design of the program will allow ease in such changes. Initial candidates for insertion are elements of the model formulation that were not included in this example model. These include:

- Treatment of exogenous additions to operating funds
- Technological impact on production formulas as R&D expenditures cumulate
- Consideration of maximum demand thresholds as well as minimum thresholds.

Even without the additional procedural changes, SOS-Q appears ready to be of some assistance as a rough analysis tool, after the initial adjustments are performed (interpolations, data expansions, improvement of data).

The development plan for SOS-D appears to be a long-term venture. As such, it appears appropriate that the process begin with an applications analysis to determine what class of problems are likely to be addressed by SOS-D. From this should be produced a useful, evolving development/applications plan so that partial use of the SOS model is available early in the development and then both activities (use/refinement) can continue.

While the initial steps to changing the model to a more detailed form are straight-forward, considerable planning should be introduced to lessen the burden of data collection and output data reduction on the later users; therefore, the application study should be followed by a development of general (but specific) model design effort that sets context and goals for the follow-on detailed designs of the individual model elements. As development and use of SOS-D suggest changes, periodic updates to the general design should be done.

SECTION X

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SECTION XI

APPENDICES

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APPENDIX 1

MEASURING QUALITY OF LIFE

A measure of the Quality of Life can be generated in a number of ways. It can be a series of measures which attempt to encompass all of the relevant parameters; or it can involve an additional step and turn the series of indices into a single index. There is much to be said for both attempts. Since the set of indices are components of the latter, we shall only investigate the process of developing the single index here. This index for Quality of Life is to consist of three parts -- a Preference Function, Indicators of Status, and Resource Costs. A combination of these three parts could be used to yield an expression used as a measure of the Quality of Life.

The Preference Function is a construct, highly theoretical in nature, used to represent a numerical measure of that illusive thing the sociologists call culture. If culture as a learned and inculcated feature of human existence has any meaning, and if the psychologists' premise, that deeply held beliefs control both our individual and group actions, has validity, then this Preference Function should be able to be approximated. One possible way of operationalizing this is to give the random group of people a finite number of points to distribute among the selected factors. The average of these weightings would yield a distribution which should be a useful approximation of the Preference Function of the society represented by the group and, as such, should provide a guide to the society's long-run actions.

As this paper is not meant to be an exhaustive treatment of any of these concepts, we shall settle for an overall explanation of them and a general discussion of their properties. Consequently, the Preference Function can be viewed as a measure of the relative importance of selected features of a region and its society to the members of that society. The approach is simplicity itself in that it consists of a relative ranking of the factors which make up the Quality of Life by a randomly chosen sample of the people in the particular society. As theory, it suggests that given a series of items [a, b, c, d, e] a randomly selected group of the society can rank them in order of importance, such that they reflect the preferences of the people for the chosen items. The same measure could be used for sub-sectors of the society.* A sample of this is presented as Figure 1-1.

Without delving into setting the Preference Function further at this point, let us consider the Indicators of Status. Assuming that we have agreed upon a set of measures which define the Quality of Life and have weighted these among themselves, then it is necessary to actually quantify the state of the society in terms of these same factors. In other words, where is the system in relation to where it wishes to be? Such measures could be constructed as a series of indices and each of these indicators can be looked upon as a satisfaction index which relates an element of the desired and observed state of the system at a particular point in time.

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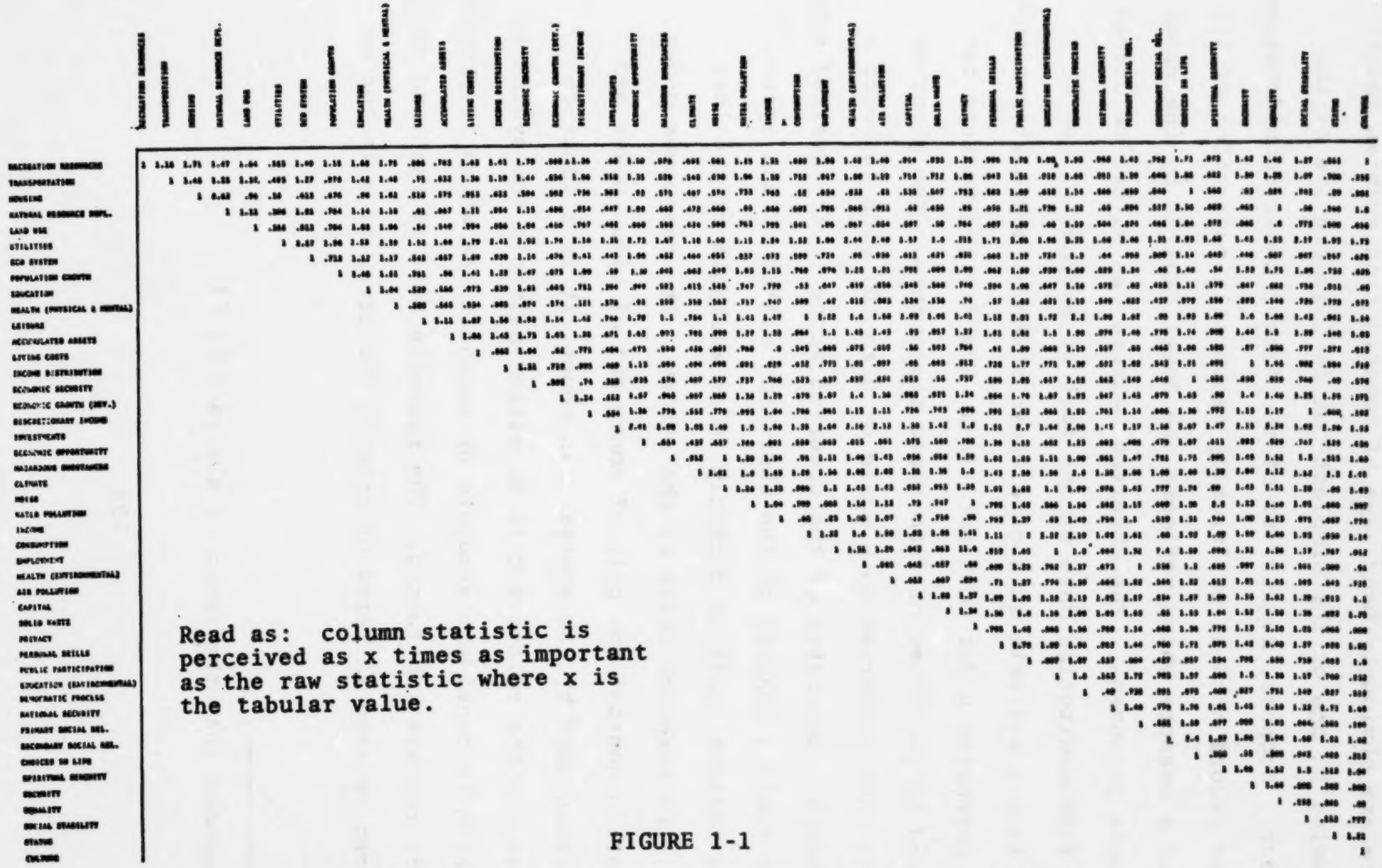
* See Mann and Hobson (1) for operational use of a similar concept.



Read as: column statistic is perceived as x times as important as the raw statistic where x is the tabular value.

FIGURE 1-1

TABULATION OF RELATIVE IMPORTANCE OF QOL COMPONENTS

There are obviously many ways of constructing such an index; the following is one of the simplest but is illustrative of the methodology. Suppose, regardless of the factor under consideration, we plan to record both an empirically measurable reflection of its status and a measure which reflects the level desired by the group for the same phenomena. The observed measure can either be directly obtained from monitoring data of one sort of another or can be obtained from a suitable surrogate whose movement correlates highly with the parameter under consideration. The desired measure can be obtained by interview or from goals statements. The observed measure is then converted to a scale of 0 to 10, with 10 being a perfect score. The ratio of the observed score to the desired score will then yield a measure of the short-run status of the system.[2]

This measure leads us directly to an analysis of the last function, the Resource Costs of the system. The resources under consideration consist not only of money but of time, power and other factors used by the system. In short, it is a function which measures the relative cost to either maintain the system at levels which it considers adequate or expenditures which it proposes to make to redress imbalances. The resource cost is measured so that it can be seen in terms of raising the level of a factor by one unit.

---

[2] It is assumed that the ratio is always $0 \leqslant r \leqslant 1$.

The combination of these three functions in a single expression gives us a rather interesting trade-off probability curve. Consider the Indicators of Status for three factors, where each index individually has a maximum of 100. Then the general form of the Quality of Life Index would become:

$$Max \left[\sum_{i=1}^{n} \omega_i \bar{I}_i \right] = 100$$

Therefore, the closer the system is to satisfying its desires, the higher will be its Quality of Life. Additionally the closer the measure value will be to 100. The measure also allows us to predict which factors in the equation will likely be the greatest increase in expenditures in a given year if the planner attempts to maximize Quality of Life. They are those items which are (1) very important to the system as meausred by its Preference Function value (which, remember, is the long-run indicator of system performance) (2) low in terms of its observed Indicator of Status and (3) most cost effective to redress (eg. cost is low to performance increase) will receive the most attention, at least until the item in question is no longer out of balance and therefore has a decreasing marginal toward increasing the Quality of Life.

This paradigm of a society allows us not only to explain a number of events which have occurred throughout history, but, if measurement could be implemented, it could give us a powerful tool for forecasing future events. For example, theoretical structure behind the Preference Function suggests that the society's intrisic values structure is quite rigid and the society will go to some lengths to maintain it. Elements within the structure, of course, are subject to change over time, but many take relatively long periods to change in order to readjust the societal equilibrium.

On the other hand, it is possible to influence this Function in the short run, say through the media. A concerted effort on the part of the public or private sector to emphasize one or more segments or factors can temporarily change weights in the Preference Function and cause the society to allocate resources in a fashion that it ordinarily would not have without media influence. To the extent that this preference change becomes imbedded in the society, the Preference Function is actually changed and is no longer temporary. If it is not, then the influence is of the nature of a fad and the Function swings back to an equilibrium position close to the original values. The current interest in the environment is a case in point. It is obvious that the environment and its problems did not suddenly come into being, but that the interest evidenced in it recently has come about because of a concerted effort on the part of many groups to make us more aware of the dangers and needs of our physical support system. To the extent that those who are most concerned succeed in implanting an "environmental ethic," then the Preference Function will be permanently readjusted to reflect this change in the ethos of society. The extent to which they fail provides the degree by which the present trend is a fad.

Let us look at the other parts of our equation. Possibly the most controversial portion of this construct is the ability to get measingful desired and observed values of measures described as making up the Quality of Life. As noted earlier, much effort has gone into the construction of indicators and yet the effort never seems to climb out of the infancy stage. Work needs to be done to determine both the procedures to measure the factors selected and whether the factors and indicators chosen are useful indicators of the value that are to be measured.

Finally, the concept of resource cost and effectiveness is hard to get at. The idea of the "biggest bang for the buck" is intuitively easy to grasp and is often difficult enough to derive when just economic factors are considered. When other, non-monetary, resources are added in, the data problem is magnified several times.

REFERENCES

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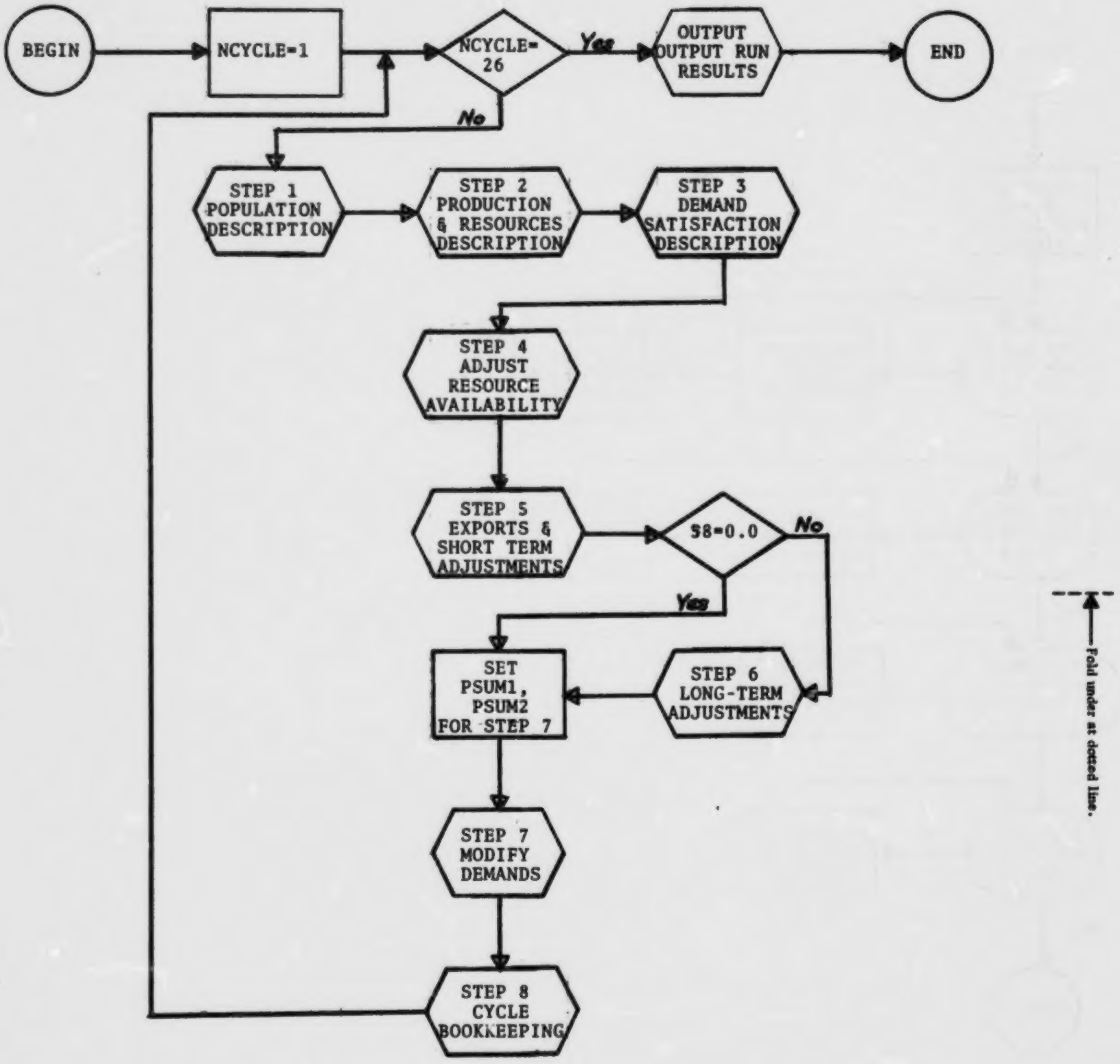
APPENDIX 2

PROGRAM FLOWCHARTS

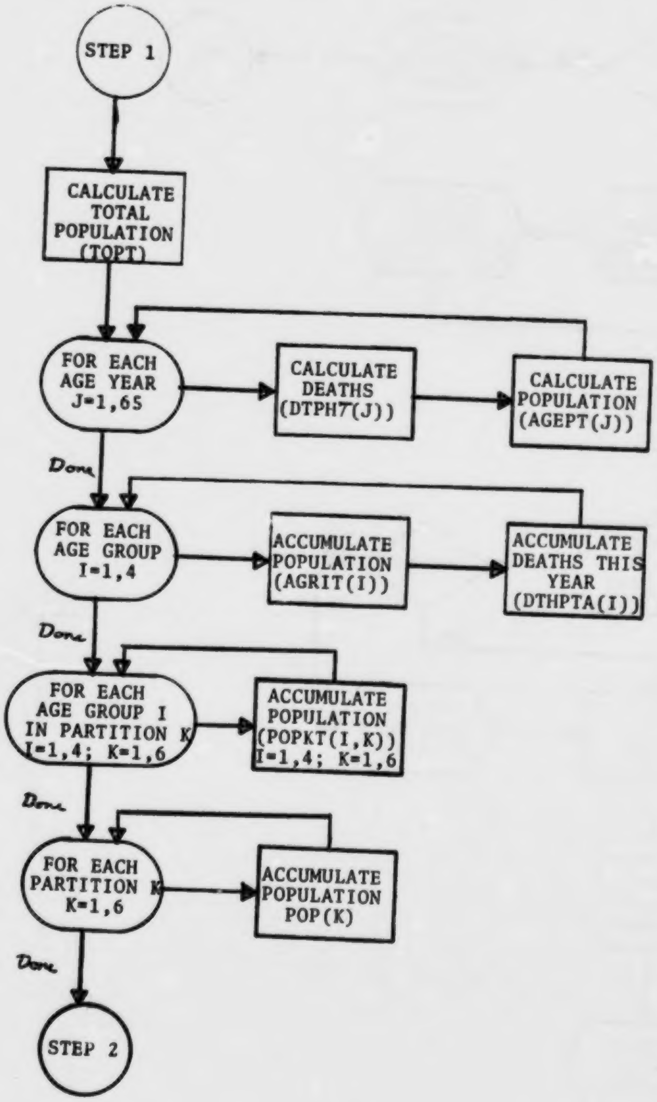
FLOWCHART 2-1

THE SOS-1 EXECUTIVE PROGRAM, MAIN


BEGIN
NCYCLE=1
NCYCLE=26
Yes
OUTPUT
OUTPUT RUN
RESULTS
END
No
STEP 1
POPULATION
DESCRIPTION
STEP 2
PRODUCTION
& RESOURCES
DESCRIPTION
STEP 3
DEMAND
SATISFACTION
DESCRIPTION
STEP 4
ADJUST
RESOURCE
AVAILABILITY
STEP 5
EXPORTS &
SHORT TERM
ADJUSTMENTS
S8=0.0
No
Yes
SET
PSUM1,
PSUM2
FOR STEP 7
STEP 6
LONG-TERM
ADJUSTMENTS
STEP 7
MODIFY
DEMANDS
STEP 8
CYCLE
BOOKKEEPING
Fold under at dotted line.

FLOWCHART 2-2

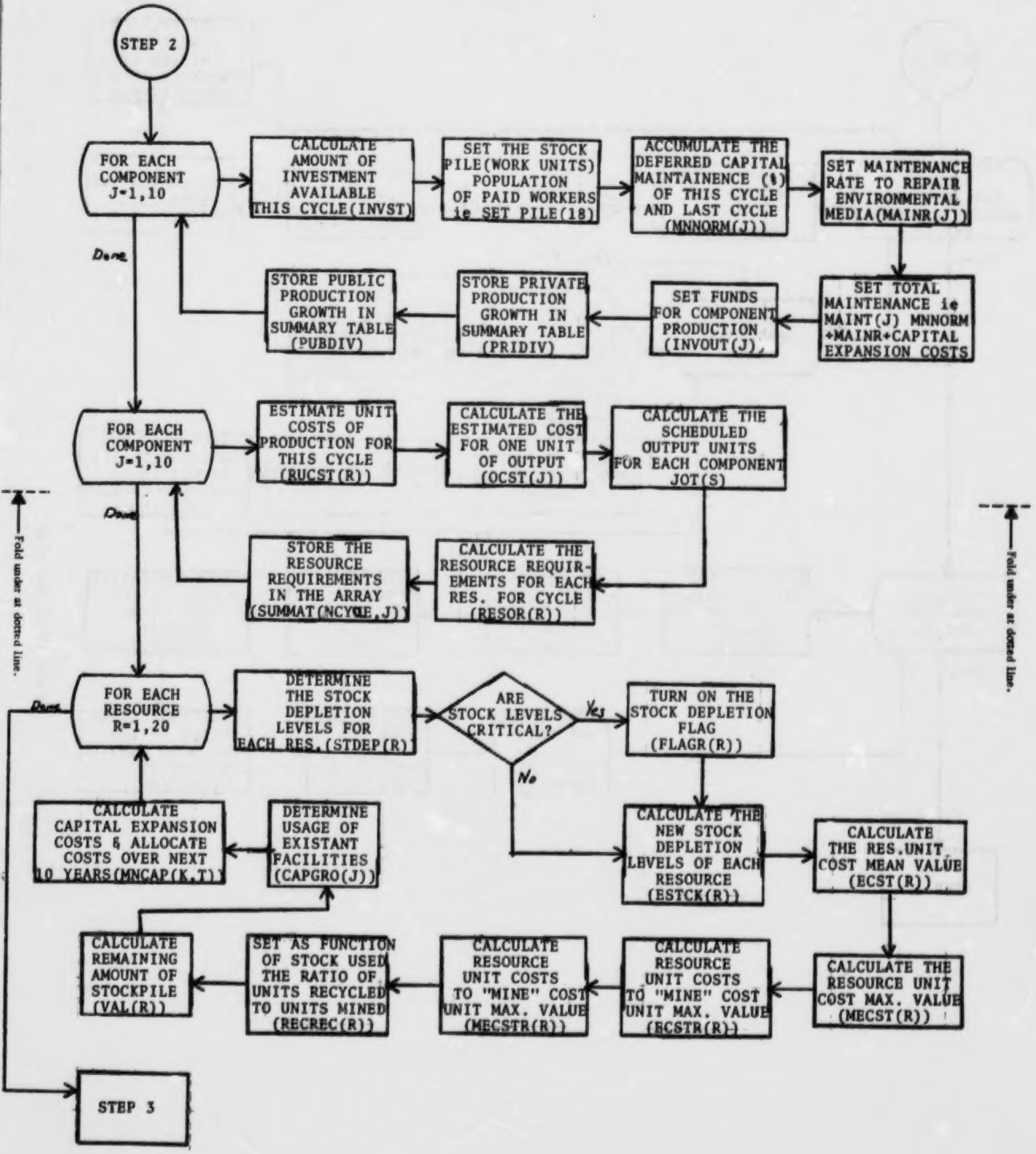
STEP 1: DESCRIBE THE POPULATION


STEP 1
CALCULATE TOTAL POPULATION (TOPT)
FOR EACH AGE YEAR J=1,65
CALCULATE DEATHS (DTPH7(J))
CALCULATE POPULATION (AGEPT(J))
Done
FOR EACH AGE GROUP I=1,4
ACCUMULATE POPULATION (AGRIT(I))
ACCUMULATE DEATHS THIS YEAR (DTHPTA(I))
Done
FOR EACH AGE GROUP I IN PARTITION K I=1,4; K=1,6
ACCUMULATE POPULATION (POPKT(I,K)) I=1,4; K=1,6
Done
FOR EACH PARTITION K K=1,6
ACCUMULATE POPULATION POP(K)
Done
STEP 2

Fold under at dotted line.

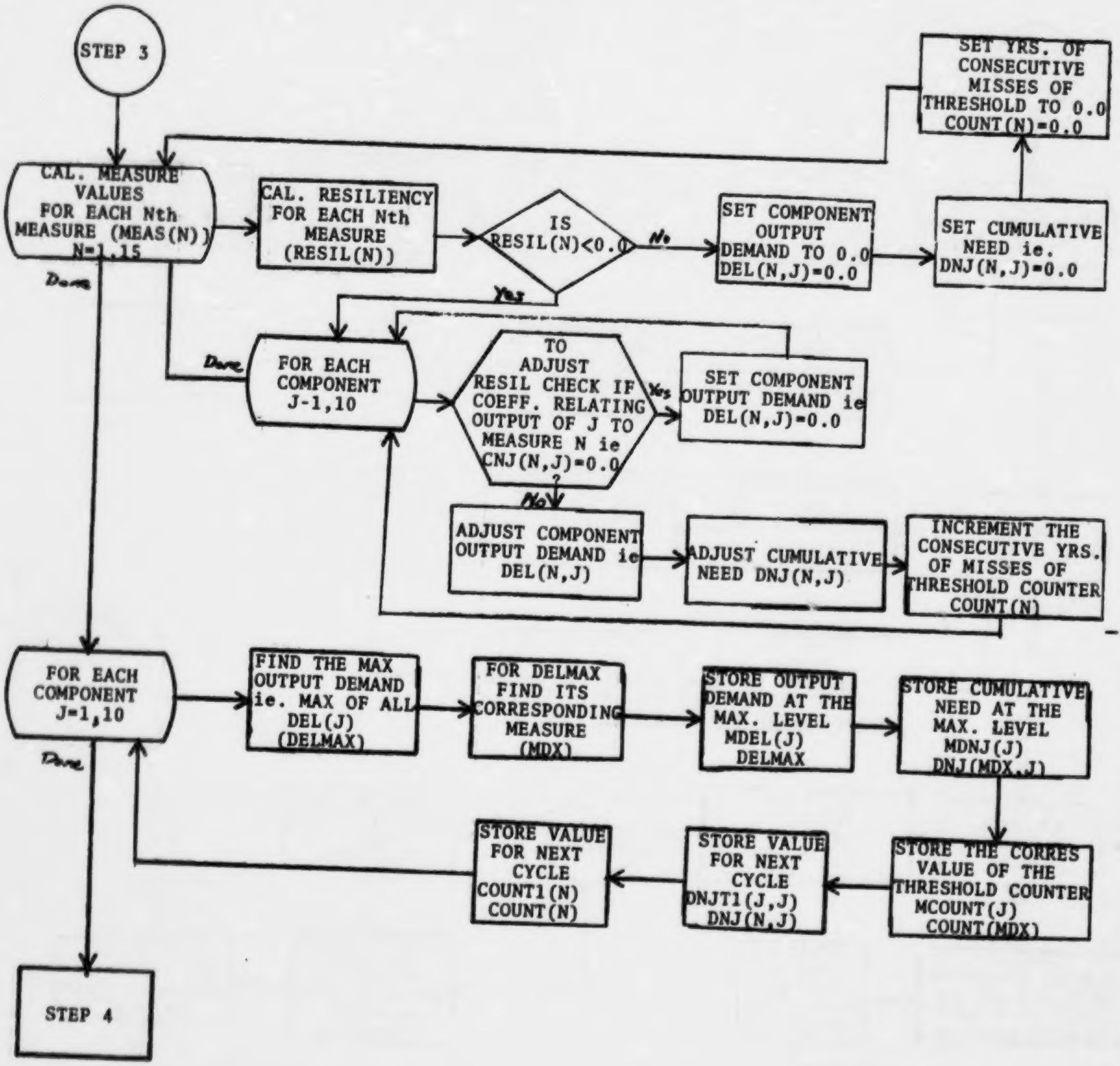
FLOWCHART 2-3

STEP 2: DESCRIBE THE PRODUCTION COMPONENTS


STEP 2
FOR EACH COMPONENT J=1,10
CALCULATE AMOUNT OF INVESTMENT AVAILABLE THIS CYCLE(INVST)
SET THE STOCK PILE(WORK UNITS) POPULATION OF PAID WORKERS ie SET PILE(18)
ACCUMULATE THE DEFERRED CAPITAL MAINTAINENCE ($) OF THIS CYCLE AND LAST CYCLE (MNNORM(J))
SET MAINTENANCE RATE TO REPAIR ENVIRONMENTAL MEDIA(MAINR(J))
SET TOTAL MAINTENANCE ie MAINT(J) MNNORM +MAINR+CAPITAL EXPANSION COSTS
SET FUNDS FOR COMPONENT PRODUCTION (INVOUT(J))
STORE PRIVATE PRODUCTION GROWTH IN SUMMARY TABLE (PRIDIV)
STORE PUBLIC PRODUCTION GROWTH IN SUMMARY TABLE (PUBDIV)
Done
FOR EACH COMPONENT J=1,10
ESTIMATE UNIT COSTS OF PRODUCTION FOR THIS CYCLE (RUCST(R))
CALCULATE THE ESTIMATED COST FOR ONE UNIT OF OUTPUT (OCST(J))
CALCULATE THE SCHEDULED OUTPUT UNITS FOR EACH COMPONENT JOT(S)
CALCULATE THE RESOURCE REQUIR-EMENTS FOR EACH RES. FOR CYCLE (RESOR(R))
STORE THE RESOURCE REQUIREMENTS IN THE ARRAY (SUMMAT(NCYCLE,J))
Done
FOR EACH RESOURCE R=1,20
DETERMINE THE STOCK DEPLETION LEVELS FOR EACH RES.(STDEP(R))
ARE STOCK LEVELS CRITICAL?
Yes
No
TURN ON THE STOCK DEPLETION FLAG (FLAGR(R))
CALCULATE THE NEW STOCK DEPLETION LEVELS OF EACH RESOURCE (ESTCK(R))
CALCULATE THE RES.UNIT COST MEAN VALUE (ECST(R))
CALCULATE THE RESOURCE UNIT COST MAX. VALUE (MECST(R))
CALCULATE RESOURCE UNIT COSTS TO "MINE" COST UNIT MAX. VALUE (ECSTR(R))
CALCULATE RESOURCE UNIT COSTS TO "MINE" COST UNIT MAX. VALUE (MECSTR(R))
SET AS FUNCTION OF STOCK USED THE RATIO OF UNITS RECYCLED TO UNITS MINED (RECREC(R))
CALCULATE REMAINING AMOUNT OF STOCKPILE (VAL(R))
DETERMINE USAGE OF EXISTANT FACILITIES (CAPGRO(J))
CALCULATE CAPITAL EXPANSION COSTS & ALLOCATE COSTS OVER NEXT 10 YEARS(MNCAP(K,T))
Done
STEP 3
Fold under at dotted line.
Fold under at dotted line.

FLOWCHART 2-4

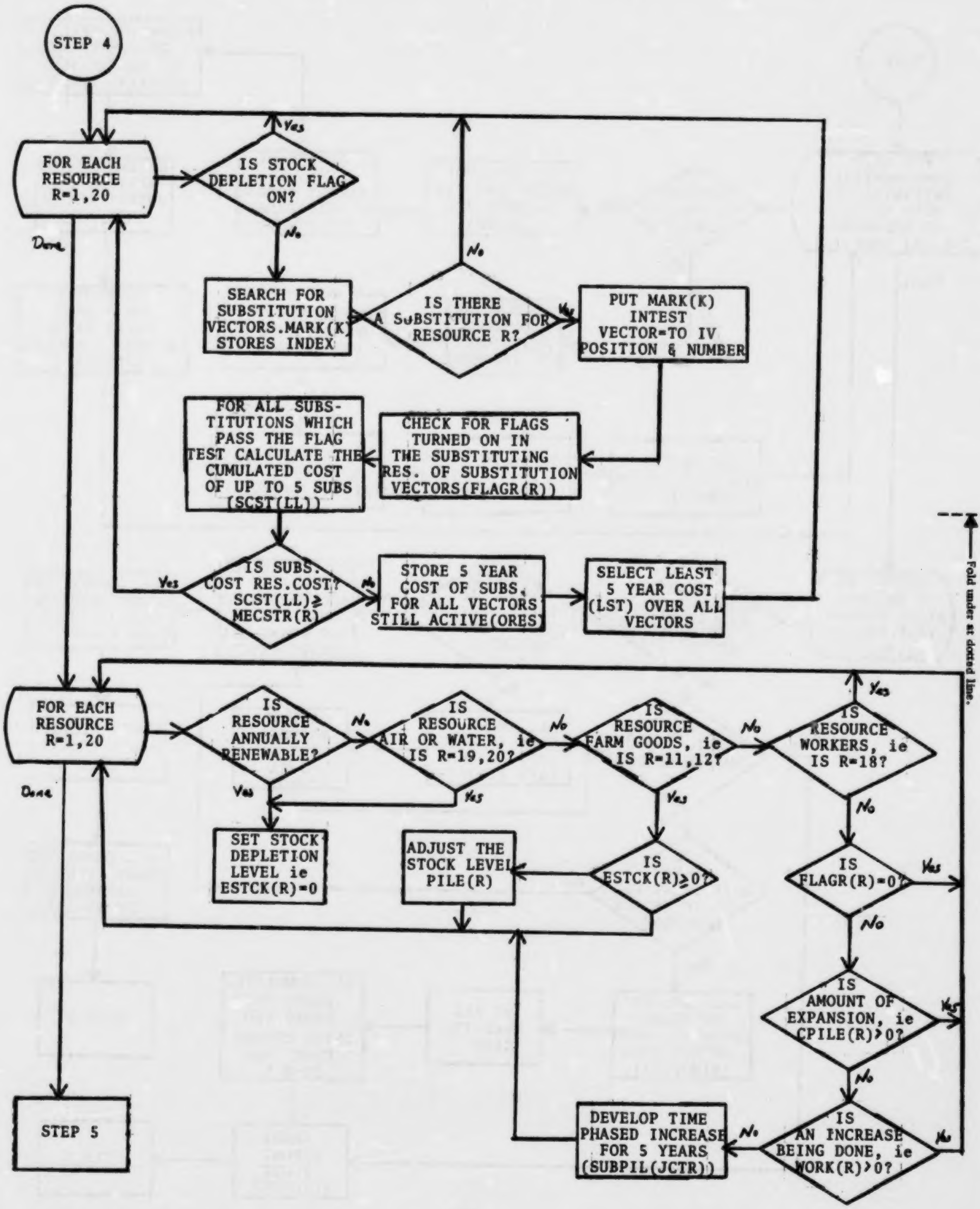
STEP 3: DESCRIBE THE STATE OF THE SYSTEM


STEP 3
CAL. MEASURE VALUES FOR EACH Nth MEASURE (MEAS(N)) N=1,15
CAL. RESILIENCY FOR EACH Nth MEASURE (RESIL(N))
IS RESIL(N)<0.0
No
SET COMPONENT OUTPUT DEMAND TO 0.0 DEL(N,J)=0.0
SET CUMULATIVE NEED ie. DNJ(N,J)=0.0
SET YRS. OF CONSECUTIVE MISSES OF THRESHOLD TO 0.0 COUNT(N)=0.0
Yes
Done
Done
FOR EACH COMPONENT J-1,10
TO ADJUST RESIL CHECK IF COEFF. RELATING OUTPUT OF J TO MEASURE N ie CNJ(N,J)=0.0 ?
Yes
SET COMPONENT OUTPUT DEMAND ie DEL(N,J)=0.0
No
ADJUST COMPONENT OUTPUT DEMAND ie DEL(N,J)
ADJUST CUMULATIVE NEED DNJ(N,J)
INCREMENT THE CONSECUTIVE YRS. OF MISSES OF THRESHOLD COUNTER COUNT(N)
FOR EACH COMPONENT J=1,10
FIND THE MAX OUTPUT DEMAND ie. MAX OF ALL DEL(J) (DELMAX)
FOR DELMAX FIND ITS CORRESPONDING MEASURE (MDX)
STORE OUTPUT DEMAND AT THE MAX. LEVEL MDEL(J) DELMAX
STORE CUMULATIVE NEED AT THE MAX. LEVEL MDNJ(J) DNJ(MDX,J)
STORE THE CORRES VALUE OF THE THRESHOLD COUNTER MCOUNT(J) COUNT(MDX)
STORE VALUE FOR NEXT CYCLE DNJT1(J,J) DNJ(N,J)
STORE VALUE FOR NEXT CYCLE COUNT1(N) COUNT(N)
Done
STEP 4

Fold under at dotted line.

FLOWCHART 2-5

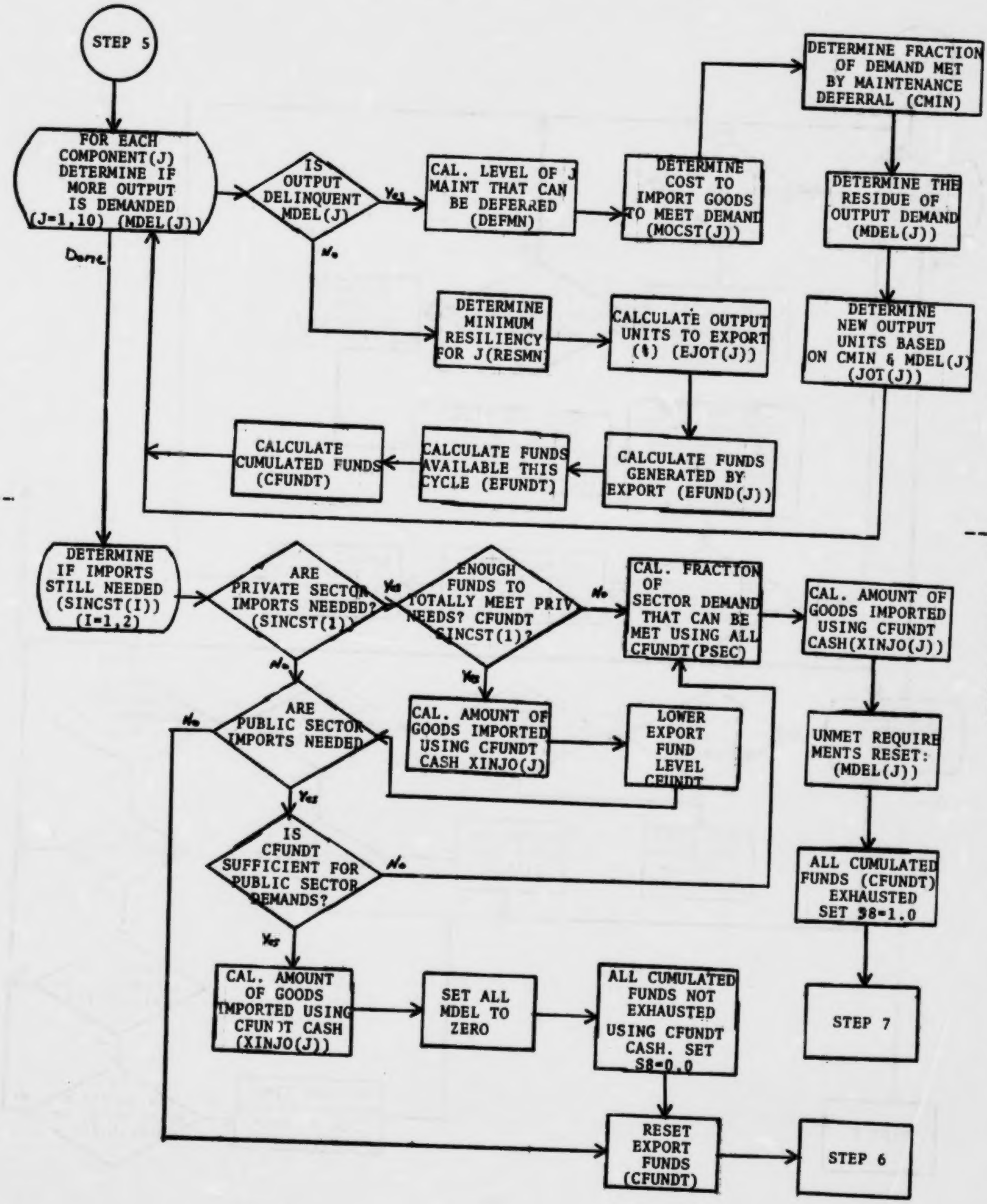
STEP 4: ADJUST RESOURCE RESERVES & UTILIZATION FACTORS


STEP 4
FOR EACH RESOURCE R=1,20
Done
IS STOCK DEPLETION FLAG ON?
Yes
No
SEARCH FOR SUBSTITUTION VECTORS.MARK(K) STORES INDEX
IS THERE A SUBSTITUTION FOR RESOURCE R?
No
Yes
PUT MARK(K) INTEST VECTOR=TO IV POSITION & NUMBER
CHECK FOR FLAGS TURNED ON IN THE SUBSTITUTING RES. OF SUBSTITUTION VECTORS(FLAGR(R))
FOR ALL SUBSTITUTIONS WHICH PASS THE FLAG TEST CALCULATE THE CUMULATED COST OF UP TO 5 SUBS [SCST(LL))
IS SUBS. COST RES.COST? SCST(LL)≥ MECSTR(R)
Yes
No
STORE 5 YEAR COST OF SUBS, FOR ALL VECTORS STILL ACTIVE(ORES)
SELECT LEAST 5 YEAR COST (LST) OVER ALL VECTORS
FOR EACH RESOURCE R=1,20
Done
IS RESOURCE ANNUALLY RENEWABLE?
No
Yes
IS RESOURCE AIR OR WATER, ie IS R=19,20?
No
Yes
IS RESOURCE FARM GOODS, ie IS R=11,12?
No
Yes
IS RESOURCE WORKERS, ie IS R=18?
Yes
No
SET STOCK DEPLETION LEVEL ie ESTCK(R)=0
ADJUST THE STOCK LEVEL PILE(R)
IS ESTCK(R)≥0?
IS FLAGR(R)=0?
Yes
No
IS AMOUNT OF EXPANSION, ie CPILE(R)>0?
Yes
No
IS AN INCREASE BEING DONE, ie WORK(R)>0?
No
No
DEVELOP TIME PHASED INCREASE FOR 5 YEARS (SUBPIL(JCTR))
STEP 5

Fold under at dotted line.

FLOWCHART 2-6

STEP 5: PERFORM SHORT TERM OUTPUT ADJUSTMENTS


STEP 5
FOR EACH COMPONENT(J) DETERMINE IF MORE OUTPUT IS DEMANDED (J=1,10) (MDEL(J))
Done
IS OUTPUT DELINQUENT MDEL(J)
Yes
No
CAL. LEVEL OF J MAINT THAT CAN BE DEFERRED (DEFMN)
DETERMINE COST TO IMPORT GOODS TO MEET DEMAND (MOCST(J))
DETERMINE FRACTION OF DEMAND MET BY MAINTENANCE DEFERRAL (CMIN)
DETERMINE THE RESIDUE OF OUTPUT DEMAND (MDEL(J))
DETERMINE NEW OUTPUT UNITS BASED ON CMIN & MDEL(J) (JOT(J))
DETERMINE MINIMUM RESILIENCY FOR J(RESMN)
CALCULATE OUTPUT UNITS TO EXPORT ($) (EJOT(J))
CALCULATE FUNDS GENERATED BY EXPORT (EFUND(J))
CALCULATE FUNDS AVAILABLE THIS CYCLE (EFUNDT)
CALCULATE CUMULATED FUNDS (CFUNDT)
DETERMINE IF IMPORTS STILL NEEDED (SINCST(I)) (I=1,2)
ARE PRIVATE SECTOR IMPORTS NEEDED? (SINCST(1))
Yes
No
ENOUGH FUNDS TO TOTALLY MEET PRIV NEEDS? CFUNDT SINCST(1)?
No
Yes
CAL. FRACTION OF SECTOR DEMAND THAT CAN BE MET USING ALL CFUNDT(PSEC)
CAL. AMOUNT OF GOODS IMPORTED USING CFUNDT CASH(XINJO(J))
UNMET REQUIREMENTS RESET: (MDEL(J))
ALL CUMULATED FUNDS (CFUNDT) EXHAUSTED SET S8=1.0
STEP 7
CAL. AMOUNT OF GOODS IMPORTED USING CFUNDT CASH XINJO(J)
LOWER EXPORT FUND LEVEL CFUNDT
ARE PUBLIC SECTOR IMPORTS NEEDED
No
Yes
IS CFUNDT SUFFICIENT FOR PUBLIC SECTOR DEMANDS?
No
Yes
CAL. AMOUNT OF GOODS IMPORTED USING CFUNDT CASH (XINJO(J))
SET ALL MDEL TO ZERO
ALL CUMULATED FUNDS NOT EXHAUSTED USING CFUNDT CASH. SET S8=0.0
RESET EXPORT FUNDS (CFUNDT)
STEP 6

Fold under at dotted line.

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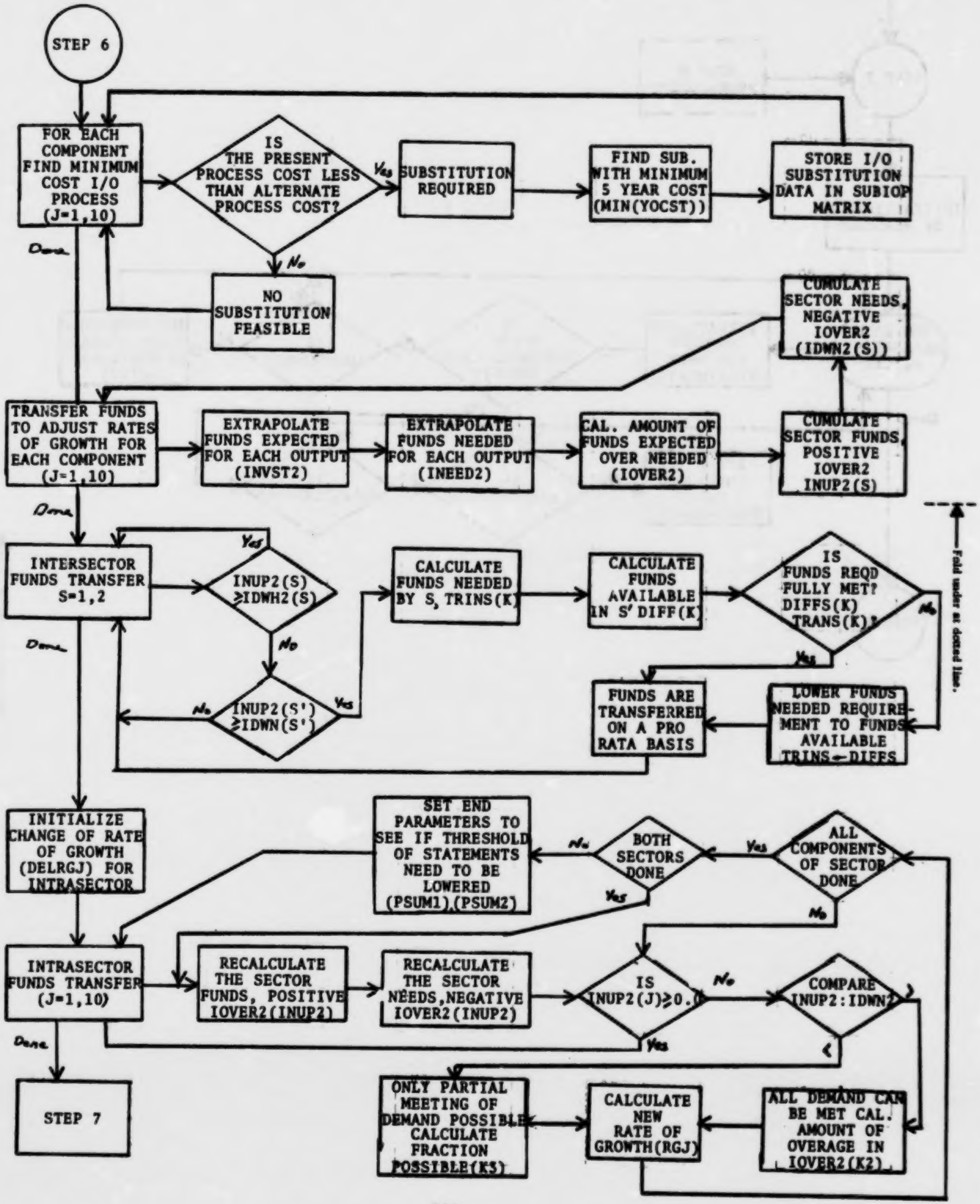
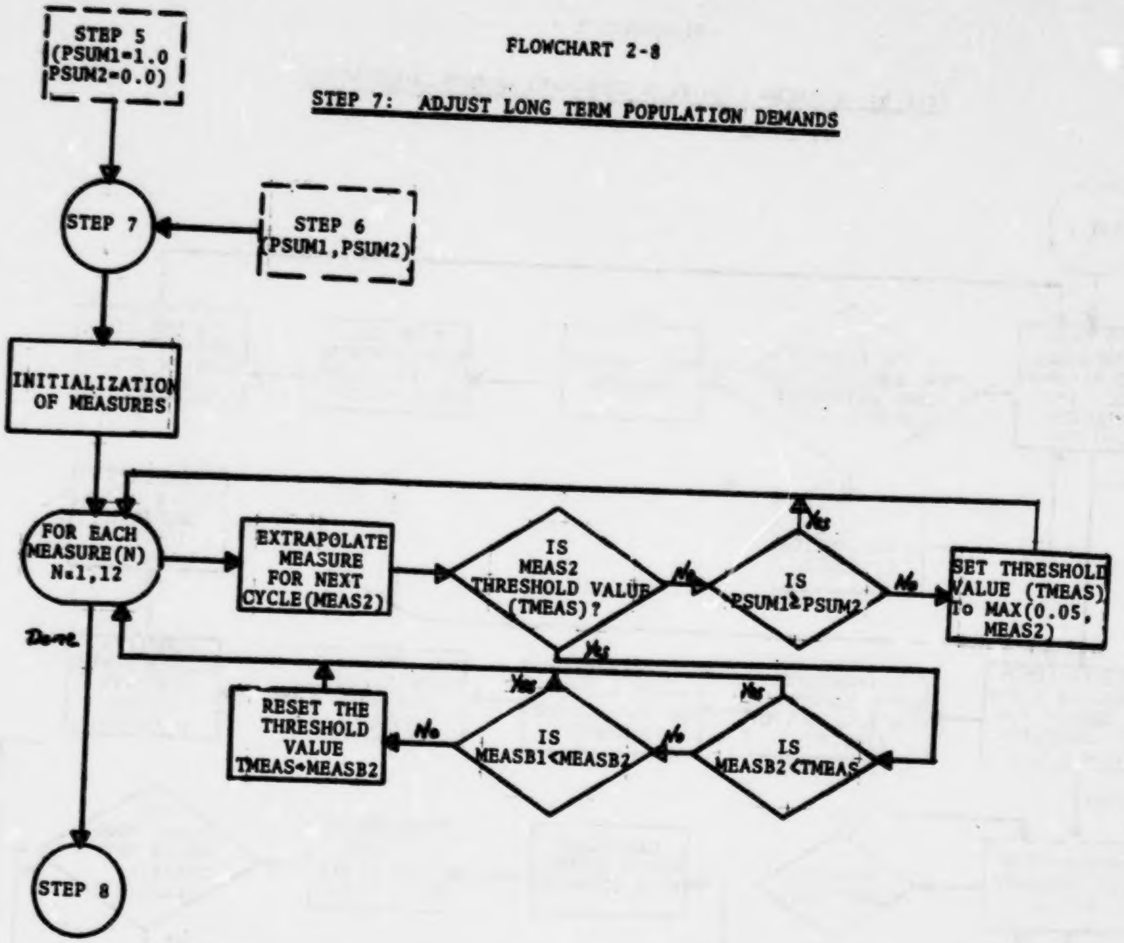
FLOWCHART 2-7

STEP 6: PERFORM LONG TERM COMPONENT OUTPUT ADJUSTMENTS


STEP 6
FOR EACH COMPONENT FIND MINIMUM COST I/O PROCESS (J=1,10)
IS THE PRESENT PROCESS COST LESS THAN ALTERNATE PROCESS COST?
Yes
SUBSTITUTION REQUIRED
FIND SUB. WITH MINIMUM 5 YEAR COST (MIN(YOCST))
STORE I/O SUBSTITUTION DATA IN SUBIOP MATRIX
No
NO SUBSTITUTION FEASIBLE
Done
CUMULATE SECTOR NEEDS, NEGATIVE IOVER2 (IDWN2(S))
TRANSFER FUNDS TO ADJUST RATES OF GROWTH FOR EACH COMPONENT (J=1,10)
EXTRAPOLATE FUNDS EXPECTED FOR EACH OUTPUT (INVST2)
EXTRAPOLATE FUNDS NEEDED FOR EACH OUTPUT (INEED2)
CAL. AMOUNT OF FUNDS EXPECTED OVER NEEDED (IOVER2)
CUMULATE SECTOR FUNDS, POSITIVE IOVER2 INUP2(S)
Done
INTERSECTOR FUNDS TRANSFER S=1,2
Yes
INUP2(S) ≥IDWH2(S)
No
CALCULATE FUNDS NEEDED BY S, TRINS(K)
CALCULATE FUNDS AVAILABLE IN S' DIFF(K)
IS FUNDS REQD FULLY MET? DIFFS(K) TRANS(K)?
No
Yes
Done
No
INUP2(S') ≥IDWN(S')
Yes
FUNDS ARE TRANSFERRED ON A PRO RATA BASIS
LOWER FUNDS NEEDED REQUIREMENT TO FUNDS AVAILABLE TRINS←DIFFS
Fold under at dotted line.
INITIALIZE CHANGE OF RATE OF GROWTH (DELRGJ) FOR INTRASECTOR
SET END PARAMETERS TO SEE IF THRESHOLD OF STATEMENTS NEED TO BE LOWERED (PSUM1),(PSUM2)
No
BOTH SECTORS DONE
Yes
ALL COMPONENTS OF SECTOR DONE
Yes
No
INTRASECTOR FUNDS TRANSFER (J=1,10)
RECALCULATE THE SECTOR FUNDS, POSITIVE IOVER2(INUP2)
RECALCULATE THE SECTOR NEEDS,NEGATIVE IOVER2(INUP2)
IS INUP2(J)≥0.0
No
COMPARE INUP2:IDWN2
>
<
Yes
Done
STEP 7
ONLY PARTIAL MEETING OF DEMAND POSSIBLE CALCULATE FRACTION POSSIBLE(K3)
CALCULATE NEW RATE OF GROWTH(RGJ)
ALL DEMAND CAN BE MET CAL. AMOUNT OF OVERAGE IN IOVER2(K2)

FLOWCHART 2-8

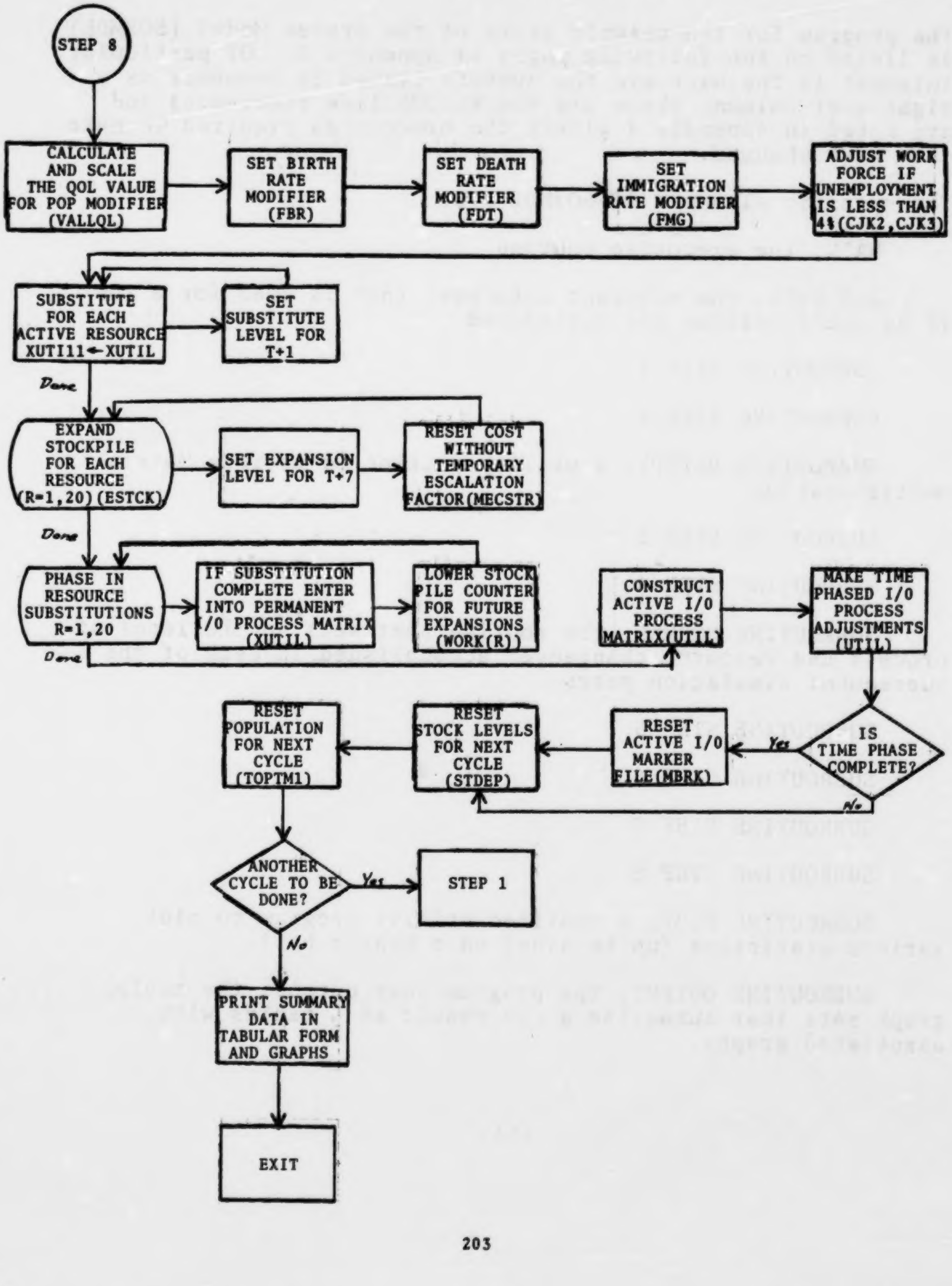
STEP 7: ADJUST LONG TERM POPULATION DEMANDS


STEP 5
(PSUM1=1.0
PSUM2=0.0)
STEP 7
STEP 6
(PSUM1,PSUM2)
INITIALIZATION OF MEASURES
FOR EACH MEASURE(N) N=1,12
EXTRAPOLATE MEASURE FOR NEXT CYCLE (MEAS2)
IS MEAS2 THRESHOLD VALUE (TMEAS)?
No
IS PSUM1≥PSUM2
Yes
No
SET THRESHOLD VALUE (TMEAS) To MAX(0.05, MEAS2)
Yes
Done
Yes
Yes
RESET THE THRESHOLD VALUE TMEAS=MEASB2
No
IS MEASB1<MEASB2
No
IS MEASB2<TMEAS
STEP 8

Fold under at dotted line.

FLOWCHART 2-9

STEP 8: RESET DATA BASE FOR NEXT CYCLE


STEP 8
CALCULATE AND SCALE THE QOL VALUE FOR POP MODIFIER (VALLQL)
SET BIRTH RATE MODIFIER (FBR)
SET DEATH RATE MODIFIER (FDT)
SET IMMIGRATION RATE MODIFIER (FMG)
ADJUST WORK FORCE IF UNEMPLOYMENT IS LESS THAN 4% (CJK2, CJK3)
SUBSTITUTE FOR EACH ACTIVE RESOURCE XUTI11←XUTIL
SET SUBSTITUTE LEVEL FOR T+1
Done
EXPAND STOCKPILE FOR EACH RESOURCE (R=1,20) (ESTCK)
SET EXPANSION LEVEL FOR T+7
RESET COST WITHOUT TEMPORARY ESCALATION FACTOR (MECSTR)
Done
PHASE IN RESOURCE SUBSTITUTIONS R=1,20
IF SUBSTITUTION COMPLETE ENTER INTO PERMANENT I/O PROCESS MATRIX (XUTIL)
LOWER STOCK PILE COUNTER FOR FUTURE EXPANSIONS (WORK(R))
Done
CONSTRUCT ACTIVE I/O PROCESS MATRIX (UTIL)
MAKE TIME PHASED I/O PROCESS ADJUSTMENTS (UTIL)
IS TIME PHASE COMPLETE?
Yes
RESET ACTIVE I/O MARKER FILE (MBRK)
No
RESET STOCK LEVELS FOR NEXT CYCLE (STDEP)
RESET POPULATION FOR NEXT CYCLE (TOPTM1)
ANOTHER CYCLE TO BE DONE?
Yes
STEP 1
No
PRINT SUMMARY DATA IN TABULAR FORM AND GRAPHS
EXIT

Fold under at dotted line.

APPENDIX 3

SOS-1 MODEL PROGRAM LISTINGS FOR OSI/EPA COMPUTER USING WYLBUR/FORTRAN-IVG

The program for the example State of the System Model (SOSMDL) is listed on the following pages of Appendix 3. Of particular interest to the user are the numbers listed in sequence as a right-most column; these are the WYLBUR line references and are cited in Appendix 4 within the procedures required to make data base changes.

The specific elements of SOSMDL are:

MAIN, the executive routine

BLK DATA, the existant data base that is used for a run if no modifications are introduced

SUBROUTINE STEP 1

SUBROUTINE STEP 2

SUBROUTINE MATMPY, a utility routine to perform matrix multiplication

SUBROUTINE STEP 3

SUBROUTINE STEP 4

SUBROUTINE NORMAL, the routine that sets up the level of process and resource changeover accomplished in each of the subsequent simulation years

SUBROUTINE STEP 5

SUBROUTINE STEP 6

SUBROUTINE STEP 7

SUBROUTINE STEP 8

SUBROUTINE PLOT, a modified utility program to plot various statistics (up to nine) on a yearly basis

SUBROUTINE OUTPUT, the program that outputs the table/graph sets that summarize a run result as 8 tables with associated graphs.

```
               C**    THIS IS THE MAIN PROGRAM                                                              6.
               C***                                                                                         7.
               C***   PARAMETER CHANGES CAN BE MADE IN:                                                     8.
               C***     BIRTHRATE (BR), IMMIGRATION RATE (MG) -- LINE 69                                    9.
               C***     INVESTMENT ANNUAL GROWTH RATES (RGJ) -- LINE 105                                   10.
               C***     THRESHOLDS OF DEMAND MEASURES (TMEAS) -- LINE 168                                  11.
               C***     HISTORICAL EXPORT RATES -- LINE 196                                                12.
               C***     RATIO OF UPPER TO LOWER THRESHOLDS (UPPER) -- LINE 229                             13.
               C***                                                                                        14.
               C***   TO MAKE A CHANGE: TYPE MOD ###(CR) WHERE ### IS THE LINE                             15.
               C***   THEN MAKE CHANGES AS PER WYLBUR RULES.                                               16.
               C***                                                                                        17.
               C***   TO CHANGE THE NUMBER OF CYCLES FROM 25 YEARS:                                        18.
               C***   TYPE MOD 31(CR), THEN CHANGE '25' TO NEW VALUE LT 101 YEARS.                         19.
               C***                                                                                        20.
               CTED THIS IS MY PLAY PRODUCTION COPY PROGRAM                                                21.
 0001                 IMPLICIT REAL*4 (A-Z)                                                                22.
 0002                 COMMON/CONST/BR,DT,DRA(65),NCYCLE,MG                                                 23.
 0003                 COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOP(20),                        24.
                     1  ESTCK(20), RSORT(10),RSORT1(10),STDEP(20),RUCST(20),MAINT(10),                     25.
                     C OCST(10),ECST(20),REREC(20),RECST(20),FLAGR(20),MRECST(20),INDX,                    26.
                     2  INVST1(10),INVST(10),JOT(10),UTIL(10,20),UTILT(20,10)                              27.
 0004                 INTEGER *4 NCYCLE                                                                    28.
 0005                 WRITE(6,1500) BR,DT,(RGJ(NCYCLE),NCYCLE=1,10)                                        29.
 0006            1500 FORMAT(1H0,T10,F5.4,2X,F5.4,10(2X,F5.2))                                             30.
 0007                 DO 100 NCYCLE = 1,25                                                                 31.
               C**    POPULATION DATA FOR CYCLE                                                            32.
 0008                 CALL STEP1                                                                           33.
               C**    PRODUCTION DATA FOR CYCLE                                                            34.
 0009                 CALL STEP2                                                                           35.
               C**    QOL MEASURES FOR CYCLE                                                               36.
 0010                 CALL STEP3                                                                           37.
               C**    STEP4 ADJUSTS RESOURCE AVAILABILITY                                                  38.
 0011                 CALL STEP4                                                                           39.
               C**    STEP5 EXPORTS AND DOES NEEDED SHORT TERM FUNDING                                     40.
 0012                 CALL STEP5(S8)                                                                       41.
               C**    IF S8=0 THEN SHORT TERM FUNDS WERE SUFFICIENT TO ADJUST                              42.
               C**       COMPONENT OUTPUT; OTHERWISE DO LONG TERM ADJUSTMENT                               43.
 0013                 IF (S8.EQ.0.0)  GO  TO  200                                                          44.
 0014                 CALL STEP6(PSUM1,PSUM2)                                                              45.
               C**     STEP7 ENTERED TO LOWER THRESHOLD LEVELS                                             46.
 0015                 GO TO 400                                                                            47.
               C**    STEP7 ENTERED ONLY TO UPGRADE THRESHOLD                                              48.
 0016             200 PSUM1=1.0                                                                            49.
 0017                 PSUM2=0.0                                                                            50.
 0018             400 CALL STEP7(PSUM1,PSUM2)                                                              51.
               C**    SET UP FOR NEXT CYCLE                                                                52.
 0019                 CALL STEP8                                                                           53.
 0020             100 CONTINUE                                                                             54.
 0021                 CALL OUTPUT                                                                          55.
 0022                 STOP                                                                                 56.
 0023                 END                                                                                  57.
 FORTRAN IV G LEVEL  21                    BLK DATA          DATF = 73311        21/32/01              PAGE 0001
 0001                 BLOCK DATA
                C**
                C      INITIALIZATION  STEP1
                C**
 0002                 IMPLICIT REAL*4 (A-Z)
                C**
 0003                 COMMON/PRINT/NPRNT1,NPRNT2
 0004                 DATA  NPRNT1/1.0/,    NPRNT2/1.0/
                C**
 0005                 COMMON/CONST/BR,DT,DRA(65),NCYCLE,MG
 0006                 INTEGER *4 NCYCLE
 0007                 DATA  BR/0.0182/,   DT/0.0094/,
                     C    DRA/6.9988,3*0.2744,0.1372,8*0.2290,0.1584,3*0.5148,3*0.4687,
                     C      4*0.4739,10*0.3985,10*0.7157,10*1.6718,10*3.0859,1605.5446/
                     C   ,NCYCLE/1/,      MG/0.0021/
                C**
 0008                 COMMON/INTER/FMG,TOPTM1,AGEPT(65),AGEPT1(65)
                     1             ,TOPT,POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)
 0009                 DATA  FMG /1.0/,TCPTM1/203210.00/,AGEPT/65*0.0/,
                     2 AGEPT1/5*3430.8,8*4581.3,4*3959.8,3*3505.7,4*3545.0,10*2390.7,
                     3         10*2308.8,10*2322.0,10*1859.0,20066.0/
 0010                 DATA TOPT/0.0/,  POPKT/24*0.0/,  AGRIT/4*0.0/
 0011                 DATA FBR /1.0/,                  FDT/1.0/
 0012                 DATA PDTH/4*0.C8,10*0.04,10*0.13,10*0.16,10*0.31,10*0.72,
                     1          10*1.66,5.775/
                C**
 0013                 CCMMON/CHAR/CJK1(6,10),CJK2(6,10),CJK3(6,10),CJK4(6,10),
                     1             C1(6),C2(6),C3(6),C4(6),JO(10),ZIP
 0014                 CATA CJK1/45863.,12*0.,372.,13*0.,122.,14*0.,5528.,104.,12*0.,
                     1   17654.,3*0.0/
 0015                 DATA CJK2/5550.,3*0.,825.,5*0.,675.,2*0.,153.,2*0.,499.35,5*0.,
                     1      1880.25,4*0.,415.,39.15,5*0.,3500.4,5*0.,2546.,0.0,1714.,52.,
                     2  2*0.,2546.,5*0.,519.3,5*0.0,17.1,2101.0/
 0016                 DATA CJK3/4*0.C,4675.0,5*0.C,3825.0,2*0.0,415.,2*C.,2829.65,
                     1   5*0.0,10654.75,4*0.0,743.,221.85,5*0.,19835.6,5*0.,10249.,
                     2   5*0.0,10249.C,2*0.0,156.,2*0.,2942.7,5*0.,96.9,22911.55/
 0017                 DATA CJK4/13*0.,496.,13*0.,18836.,15*0.,726.,16*0.0/
 0018                 DATA C1/6*0.0/,  C2/6*0.0/,  C3/6*0.0/,  C4/6*0.0/
 0019                 DATA JO/10*1000.00/,  ZIP/1.0/
                C**
                C**   INITIALIZATION STEP2
                C**
 0020                 COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOR(20),
                     1   ESTCK(20),  RSORT(10),RSORT1(10),STDEP(20),RUCST(20),MAINT(10),
                     C OCST(10),ECST(20),REREC(20),RECST(20),FLAGR(20),MRECST(20),INDX,
                     2   INVST1(10),INVST(10),JOT(10),UTIL(10,20),UTILT(20,10)
 0021                 INTEGER*4 INDX
 0022                 DATA RGJ/8.2,3.4,9.9,5.0,8.8,4.7,4.6,2.2,0.3,3.8/,
                     1 QOLT/3*0.0,2.0,0.0,10.0,3.0,7.0,5.0,4.0/,  QOLT1/10*0.0/,
                     2 MAINR/10*0.0/,
                     2      RESOR/20*0.0/,  ESTCK/20*0.0/,     RSORT/10*0.0/,
                     3      RSORT1/10*0.0/
 0023                 DATA STDEP/0.01,0.25,0.2,0.5,0.5,0.01,0.5,0.,0.,0.05,10*0.0/,
                     4      RUCST/20*0.0/,MAINT/10*0.0/,OCST/10*0.0/,ECST/20*0.0/,
                  1   REREC/20*0.0/                                                   112.
 0024              DATA  RECST/20*0.0/,  FLAGR/20*0.0/,  MRECST/20*0.0/, INDX/0/,     113.
                  1   INVST1/5690C.0,14000.,25000.,108600.,145300.,203400.,           114.
                  1   129000.,43600.,85000.,293700./, INVST/10*0.0/,JOT/10*0.0/       115.
 0025              DATA UTIL/0.,20.,3*0.,140.,20.,0.,20.,6*0.,225.,25.,4*0.,          116.
                  1      3*32.,0.,160.,32.,0.,32.,3*0.,300.,2*0.,2*2C0.,0.,           117.
                  2      100.,200.,2*0.,500.,2*0.,400.,0.,100.,4*0.,40.,2*0.,         118.
                  3      4*10.,20.,3*4.5,2*0.,18.2,4*4.5,45.,9C.,45.,2*0.,45.,90.,    119.
                  4      45.,90.,45.,800.,0.0,800.,4*400.,800.,2*400.,16*0.,          120.
                  5      150.,50.,C.,300.,8*0.,1600.,6400.,10*0.,                     121.
                  6      0.0,1500.,5*0.,750.,0.,4500.,0.,400.,3*0.,3*400.,0.,2400.,   122.
                  7  8*0.,7000.,11*0.,11200.,13000.,2800.,14000.,11200.,2800.,2800.,  123.
                  8     11200.,560C.,2*0.,2000.,3*0.,2000.,3*0.,1000.,5*0.,625.,      124.
                  9     1250.,0.0,1875.,1250.0/,                                      125.
                  A      UTILT/200*0.0/                                               126.
              C**                                                                     127.
 0026               COMMON/TWO/MECST1(20),PILE(20),PILE1(20),DPILT1(20),MNRNR1(10)    128.
                  1   ,PILET1(20),MNCAP(110,10),MJOT(10)                              129.
 0027              DATA  MECST1/.C00049,.00006,.00001,.0000011,.C0000079,.0000079,    130.
                  1.0008,.00011,.0000458,.0,.000167,.000264,0.,3*0.00001,.0,.0001033, 131.
                  2 2*0.0/                                                            132.
 0028              DATA PILE/9*10CC0.,0.,5*10000.,15000.,2*0.,2*10000.0/,             133.
                  1   PILE1/20*0.0/,  DPILT1/20*0.0/,                                 134.
                  2    MNRNR1/10*C.0/, PILET1/20*0.0/,MNCAP/1100*0.0/,MJOT/10*1000.0/ 135.
              C**                                                                     136.
 0029              COMMON/KDATA/K1(20),K2(20),K3(20),K4(20),K5(20),FLGDAT(18,4)       137.
 0030              DATA K1/4.9,4.0,0.8,2*0.0,.079,0.0,7.33,2.00,0.0,16.7,             138.
                  1          26.4,0.0,3*1.8,0.0,5.0,2*0.0/,                           139.
                  1      K2/4.9,32.0,5.2,0.132,2.000,0.158,320.8,58.7,11.19,0.0,      140.
                  2          16.7,26.4,0.0,3*0.2,0.0,5.9,2*0.0/,                      141.
                  C      K3/20*2.0/,          K4/20*0.0/,                             142.
                  3     K5/0.0,0.75,0.8,1.0,0.60,5*0.0,0.45,9*0.0/                    143.
                  4  ,FLGDAT/3*0.3,2*0.6,3*0.3,3*0.6,5*0.8,0.9,3*0.6,2*0.75,          144.
                  5              3*0.6,3*0.75,5*0.87,0.92,17*0.92,0.95,17*0.95,0.98/  145.
              C**                                                                     146.
 0031              CCMMCN/CCST/RUCST1(20),RUCST2(20),KFACT(10)                        147.
 0032              DATA  RUCST1/.000049,.00006,.00001,.0000011,.00000079,.0000079,    148.
                  1.0008,.00011,.0000458,.0,.000167,.000330,0.,3*0.000018,.0,         149.
                  2 .0001033,2*0.0/                                                   150.
 0033              DATA RUCST2/.000049,.00006,.00001,.0000011,.00000079,.0000079,     151.
                  1.0008,.00011,.C000458,.0,.000167,.000330,0.,3*0.000018,.0,         152.
                  2 .0001033,2*0.0/                                                   153.
 0034              DATA KFACT/10*C.0/                                                 154.
              C**                                                                     156.
 0035              COMMON/CAPDAT/CAPUSE(10),CAPGRC(10),REDIV(20)                      157.
 0036              DATA CAPUSE/10*0.0/,       CAPGRO/10*0.0/,  REDIV/20*0.0/          158.
              C**                                                                     159.
              C**     INITIALIZATICN STEP3                                            160.
              C**                                                                     161.
 0037              COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),DNJT1(15,10),COUNT1(15), 162.
                  1      MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                    163.
 0038              DATA  CNJ/2*806.,15*0.,1000.,15*0.,1000.,30*0.,1000.,15*0.,2*500., 164.
                  1          13*0.,2*500.,8*0.,2*194.,5*0.,1000.,15*0.,2*1000.,15*0., 165.
                  2          1000.,4*0.0/,                                            166.
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                 C       DN/1.,3*7.,4.,7.,5.,2*7.,5.,7.,4*0.0/,
                 5    TMEAS/1.26,.35,2*0.4,3.5,0.45,1.20,0.35,0.3,0.75,0.35,4*0.0/,
                 6       DNJT1/150*0.0/,                  COUNT1/15*0.0/,
                 3     MDEL/10*0.0/,  RESIL/15*0.0/,   POP/8*0.0/,
                 3    VN/3*.08,3*.1,.06,.08,.13,.06,.13,4*0.0/
                 4     , MEAS/15*0.0/
           C**
           C**   INITIALIZATION STEP4
           C**
 0039             COMMON/INTER4/SUBDAT(10,13),ORES(10,20),ROCST(10),SUBMAT(1000),
                 1   ICTR,SUBPIL(900),JCTR
 0040             INTEGER*4 ICTR,JCTR
 0041             CATA SUBDAT/2*2.,3.,4.,5.,11.,8.,9.,13.,14.,10*-1.,1.,3.,1.,
                 1           4.,5.,11.,2*7.,13.,14.,0.32,.55,.15,.4,.2,.5,2*0.02,
                 2           2*.9,2.,6.,3.,3*6.,8.,9.,14.,15.,.6,1.,.9,.06,.06,
                 3           .1,.6,.3,.03,.05,0.,2.,3*0.,7.,5*0.,.6,3*0.,.2,44*0.,
                 4           5.,1C.,3*5.,3.,2.,10.,2*1.0/
 0042             DATA    ORES/2C0*0.0/,     ROCST/10*0.0/
 0043             DATA    SUBMAT/1.0,999*0.0/,   ICTR/1/
 0044             DATA  SUBPIL/1.0,899*0.0/,    JCTR/1/
           C**
 0045             COMMON/TWORK/WCRK(20)
 0046             DATA  WORK/20*C.0/
           C**
           C**   INITIALIZATION STEP5
           C**
 0047             COMMON/INTERS/MARNCR(10),EJOT1(10),EXPO(10),CFUNDT
                 1           ,MCCST(10),IDEFMN(10),RESMN1(10)
 0048             DATA  MNRNOR/2.0,5.0,4*3.0,2*4.0,2.C,3.0/,
                 2       EJOT1/5*0.,20.,30.,10.,20.,0.0/,
                 3    EXPO/10*5.0/, CFUNDT/2.0/,  MOCST/10*1.0/,  IDEFMN/10*0.0/
                 4       ,RESMN1/10*0.3/
           C**
           C**   NEED DATA HERE FOR STEP 5 FOR ALL
           C**
           C**
           C**   INITIALIZATION STEP6
           C**
 0049             COMMON/INTER6/XUTIL(17,20),XOCST(17),MARK(17),TIME(17),CTR,
                 1  SUBIOP(1000)
 0050             INTEGER*4 CTR
 0051             DATA XUTIL/2*0.0,20.,4*0.0,3*140.,2*20.,2*0.0,2*20.,8*0.0,2*225.,
                 1  125.,2*25.,3*0.,25.,3*0.,3*32.,2*0.,3*160.,2*32.,2*0.,2*32.,
                 2  4*C.,300.,3*0.,200.,2*100.,200.,400.,0.,50.,2*100.,200.,3*0.,
                 3  500.,3*0.,40C.,2*500.,2*0.,100.,50.,6*0.,40.,3*0.,9*10.,20.,
                 4 4*4.5,3*0.0,3*18.2,7*4.5,2*45.,90.,45.,
                 5  3*0.0,45.,2*0.0,90.,3*45.,90.,135.,45.,800.,1600.,0.0,800.,
                 6  2*400.,800.,4*400.,2*800.,1200.,400.,800.,400.,17*0.0,10*0.0,
                 7  2*150.,50.,150.,2*0.0,300.,14*0.0,2*1600.,6400.,19*0.0,
                 9  1500.,9*0.0,2*750.0,2*0.0,4500.,2*0.0,400.,
                 A  4*0.0,7*400.,2*0.0,2400.,14*0.0,2*7000.,18*0.0,11200.,
                 B  5600.,13000.,2800.,14000.,11200.,5600.,2800.,4*2800.,11200.,
                 C  11200.,2*560C.,0.C,2*0.,2000.,4*0.,2000.,1000.,500.,
                 D  6*0.,1000.,7*0.,625.,2*0.,1250.,625.,2*0.,1875.,625.,1250.0/,
                E  XOCST/17*0.0/
0052             DATA MARK/1.,1.,2.,3.,4.,5.,5.,3*6.,2*7.,2*8.,2*9.,10.0/
0053             DATA TIME/15.,2*10.,30.,20.,2*5.,2*15.,5.,2*15.,4*20.,20.0/,
                1    CTR/0/,      SUBIOP/1.0,999*0.0/
          C**
          C**     INITIALIZATION STEP7
          C**
0054              COMMON/INTER7/CMEAS(15),UPPER
0055             DATA OMEAS/15*0.0/,UPPER/2.0/
          C**
          C**     INITIALIZATION STEP8
          C**
0056             COMMON/INTER8/RC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),
                1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,TMEASO(15),SCAMSO
0057             DATA  RC/0.0/,  CPILE/3*5000.,2500.,1000.,10000.,2*5000.,12*0.0/,
                2    CAPVL/90.,10.,100.,200.,300.,400.,250.,100.,200.,706.0/
0058             CATA OUTMAT/4000*0.0/
0059             DATA MBRK/1.,0.,4*1.,0.,1.,2*0.,1.,0.,1.,0.,1.,0.,1.0/
0060             CATA SUMMAT/1000*0.0/, PUBNUM/0.0/,PRIDIV/0.0/,PRINUM/0.0/
          C**
          C**    INITIALIZATION FCR CUTPUT
          C**
0061              COMMON/DPLOT/FLTMAT(10,100),PPLOT
0062              DATA  PLTMAT/1000*0.0/,   PPLOT/1.0/
0063              END
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FORTRAN IV G LEVEL  21                STEP1              DATE = 73311        21/32/01              PAGE 0001
 0001                SUBROUTINE STEP1                                                              246.
              C**                                                                                  247.
 0002                IMPLICIT REAL*4 (A-Z)                                                         248.
              C**    POPULATION LEVEL, AGE DISTRIBUTION, CHARACTERISTICS, ARE DEVELOPED            249.
 0003                COMMON/CONST/BR,DT,DRA(65),NCYCLE,MG                                          250.
 0004                INTEGER *4 NCYCLE                                                             251.
 0005                INTEGER*4 J,I,K                                                               252.
 0006                COMMON/PRINT/NPRNT1,NPRNT2                                                    253.
 0007                COMMON/INTER/FMG,TOPTM1,AGEPT(65),AGEPT1(65),TOPT,                            254.
                    1   POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)                                      255.
 0008                COMMON/CHAR/CJK1(6,10),CJK2(6,10),CJK3(6,10),CJK4(6,10),                      256.
                    1            C1(6),C2(6),C3(6),C4(6),JO(10),ZIP                               257.
 0009                COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),CNJT1(15,10),COUNT1(15),            258.
                    1     MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                               259.
 0010                COMMON/INTER8/PC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),                 260.
                    1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,TMEASO(15),SCAMSO               261.
 0011                DIMENSION XNOR(6),XNORM(6)                                                    262.
 0012                DIMENSION DAGRIT(4),DTHPT(66),DTHPTA(4)                                       263.
              C**                                                                                  264.
              C**    CALCULATE TOTAL POPULATION                                                    265.
 0013                BRTHT   =  BR * FBR                                                           266.
 0014                NTMGT   =  MG * FMG                                                           267.
 0015                DETHT=DT*FDT                                                                  268.
 0016                  TOPT=TOPTM1*(1+BRTHT-DETHT+NTMGT)                                           269.
              C**    STORE POP GROWTH IN SUMMARY TABLE                                             270.
 0017                IF (NCYCLE.GT.1) GO TO 20                                                     271.
 0018                POP(8)=TOPTM1                                                                 272.
 0019           20   SUMMAT(NCYCLE,1)=NCYCLE                                                       273.
 0020                SUMMAT(NCYCLE,2)=TOPT/POP(8)                                                  274.
              C**                                                                                  275.
              C**    AGEPT IS POP BY AGE - YEAR                                                    276.
              C**    AGRIT IS POP BY AGE GROUP                                                     277.
              C**    DTHPT IS DEATHS BY AGE-YEAR; DTHPTA IS DEATHS BY AGE GROUP                    278.
 0021                DO 30 I=1,4                                                                   279.
 0022           30   AGRIT(I)=0                                                                    280.
 0023                DO 35 I=1,4                                                                   281.
 0024           35   DTHPTA(I)=0.0                                                                 282.
              C**    THE 4 AGE GROUPS ARE:    AGES 1    TO  17                                     283.
              C**                                  18   TO  24                                     284.
              C**                                  25   TO  64                                     285.
              C**                                  65       AND ABCVE                              286.
 0025                J=1                                                                           287.
 0026                I=1                                                                           288.
              C**    XX IS BIRTHS DURING LAST YEAR                                                 289.
 0021                XX = TOPTM1*(1+NTMGT)*BRTHT                                                   290.
 002                 DTHPT(J)= XX * 2.04 * 0.01 * FDT                                              291.
 002                 DTHPTA(I)=DTHPTA(I)+DTHPT(J)                                                  292.
 003                 AGEPT(J) = XX  -  DTHPT(J)                                                    293.
 0031                AGRIT(I) = AGRIT(I) + AGEPT(J)                                                294.
 0032                DO 40 J=2,17                                                                  295.
 0033                I=1                                                                           296.
 0034                DTHPT(J)=AGEPT(J-1) * PDTH(J) * 0.01 *FDT                                     297.
 0035                DTHPTA(I)=DTHPTA(I)+DTHPT(J)                                                  298.
                                                                                                   299.
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0036              AGEPT(J) = AGEPT1(J-1) * (1+NTMGT )-DTHPT(J)                      300.
0037         40   AGRIT(I) = AGRIT(I) + AGEPT(J)                                    301.
0038              DO 50 J=18,24                                                     302.
0039              I=2                                                               303.
0040              DTHPT(J)=AGEPT(J-1) * PDTH(J) * 0.01 *FDT                         304.
0041              DTHPTA(I)=DTHPTA(I)+DTHPT(J)                                      305.
0042              AGEPT(J) = AGEPT1(J-1) * (1+NTMGT )-CTHPT(J)                      306.
0043         50   AGRIT(I) = AGRIT(I) + AGEPT(J)                                    307.
0044              DO 60 J=25,64                                                     308.
0045              I=3                                                               309.
0046              DTHPT(J)=AGEPT(J-1) * PDTH(J) * 0.01 *FDT                         310.
0047              DTHPTA(I)=DTHPTA(I)+DTHPT(J)                                      311.
0048              AGEPT(J) = AGEPT1(J-1) * (1+NTMGT )-DTHPT(J)                      312.
0049         60   AGRIT(I) = AGRIT(I) + AGEPT(J)                                    313.
           C**    AGE GROUP 65 REPRESENTS ALL OVER AND EQUAL TO AGE 65              314.
0050              J=65                                                              315.
0051              I=4                                                               316.
0052              DTHPT(J)=(AGEPT1(J)+AGEPT1(J-1))*PDTH(J)*0.01*FDT                 317.
0053              DTHPTA(I)=DTHPTA(I)+DTHPT(J)                                      318.
0054              AGEPT(J) =(AGEPT1(J)+ AGEPT1(J-1)) * (1+NTMGT )-DTHPT(J)          319.
0055              AGRIT(I) = AGRIT(I) + AGEPT(J)                                    320.
0056              POPN = 0.0                                                        321.
0057              DO 550 I=1,4                                                      322.
0058        550 POPN = PCPN + AGRIT(I)                                              323.
0059              POPN = TOPT/POPN                                                  324.
0060              DO 560 I =1,4                                                     325.
0061        560 AGRIT(I) = AGRIT(I)*POPN                                            326.
           C**                                                                      327.
           C**    'I' REPRESENTS  AGE GROUPS                    I=4                 328.
           C**    'K'             FARTITIONS WITHIN 'I'         K=6                 329.
           C**    'J'             EACH YEAR OF AGE              J=66                330.
           C**    'L'             CUTPUT COMPCNENTS             L=10                331.
           C                                                                        332.
0062              IF (NPRNT1.NE.1.0.AND.NPRNT2.NE.1.0) GO TO 502                    333.
0063              WRITE(6,500) NCYCLE                                               334.
0064        500   FORMAT(1H1,24X,'*********************************************',   335.
                1  '****',//,40X,'YEAR  IS  ',I4,//,                                336.
                2       25X'*************************************************',//)  337.
0065              GO TO 507                                                         338.
0066        502 IF (NPRNT1.EQ.1.0.CR.NPRNT2.EQ.1.0) GO TO 504                       339.
0067              GO TO 509                                                         340.
0068        504 WRITE(6,505) NCYCLE                                                 341.
0069        505 FORMAT(1H0,40X,'YEAR  IS  ',I4,//)                                  342.
0070       507    WRITE(6,503)                                                      343.
0071       503    FORMAT(10X,'****STATE  OF  THE  SYSTEM****',//)                   344.
           C**                                                                      345.
0072        509 CALL MATMPY(CJK1,JO,C1,6,10)                                        346.
0073              CALL MATMPY(CJK2,JO,C2,6,10)                                      347.
0074              CALL MATMPY(CJK3,JO,C3,6,10)                                      348.
0075              CALL MATMPY(CJK4,JO,C4,6,10)                                      349.
0076              XNOR(1) = C1(1) + C1(2) + C1(3) + C1(4) + C1(5) + C1(6)           350.
0077              XNOR(2) = C2(1) + C2(2) + C2(3) + C2(4) + C2(5) + C2(6)           351.
0078              XNOR(3) = C3(1) + C3(2) + C3(3) + C3(4) + C3(5) + C3(6)           352.
0079              XNOR(4) = C4(1) + C4(2) + C4(3) + C4(4) + C4(5) + C4(6)           353.
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             C**   POPKT(I,K) IS PCPULATION OF AGE GROUP I IN PARTITION K                354.
             C**   AGRIT*ZIP IS NORMALIZER                                               355.
 0080              DO 110 K=1,6                                                          356.
 0081              POPKT(1,K) =( C1(K)/XNOR(1))* AGRIT(1) * ZIP                          357.
 0082              POPKT(2,K) = (C2(K)/XNOR(2)) * AGRIT(2) * ZIP                         358.
 0083              POPKT(3,K) = (C3(K)/XNOR(3)) * AGRIT(3) * ZIP                         359.
 0084          110 POPKT(4,K) = (C4(K)/XNOR(4)) .* AGRIT(4) * ZIP                        360.
             C**                                                                         361.
             C**   OUTPUT STATEMENTS                                                     362.
 0085              IF (NPRNT1.NE.1.0) GC TO 401                                          363.
 0086              WRITE(6,200)                                                          364.
 0087          200 FORMAT(T50,'** REGIONAL POPULATION **',//,                            365.
                  1  T5,'AGE GROUP',T20,'POPULATION',T36,'EDUCATICN',T49,               366.
                  2  'INSTITUTION',T66,'PRESCHOOL',T80,'NON-WCPKER',                    367.
                  3  T94,'PAID WORKER',T107,'UNPAID WCRKER',/)                          368.
 0088              WRITE(6,201) TCPT                                                     369.
 0089          201 FORMAT(T7,'TOTAL',T20,F10.3)                                          370.
 0090              WRITE(6,300) AGRIT(1),(POPKT(1,K),K=1,6)                              371.
 0091          300 FORMAT(T8,'<18',T20,6(F10.3,5X),F10.3)                                372.
 0092              WRITE(6,310) AGRIT(2),(POPKT(2,K),K=1,6)                              373.
 0093          310 FORMAT(T8,'18-24',T20,6(F10.3,5X),F10.3)                              374.
 0094              WRITE(6,330) AGRIT(3),(POPKT(3,K),K=1,6)                              375.
 0095          330 FORMAT(T8,'25-65',T20,6(F10.3,5X),F10.3)                              376.
 0096              WRITE(6,340) AGRIT(4),(POPKT(4,K),K=1,6)                              377.
 0097          340 FORMAT(T8,'>65',T20,6(F10.3,5X),F10.3)                                378.
 0098          401  RETURN                                                               379.
 0099               END                                                                  380.
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0001                 SUBROUTINE STEP2                                                     381.
0002                 IMPLICIT REAL*4 (A-Z)                                                382.
               C**   THE RGJ(1) TO RGJ(5) IS PUBLIC SECTOR, RGJ(6) TO RGJ(10) IS PRIV    383.
0003                 COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOR(20),       384.
                    1  ESTCK(20), RSCRT(10),RSORT1(10),STDEP(20),RUCST(20),MAINT(10),    385.
                    C OCST(10),ECSTR(20),REREC(20),RECST(20),FLAGR(20),MECSTR(20),INDX,  386.
                    2  INVST1(10),INVST(10),JOT(10),UTIL(10,20),UTILT(20,10)             387.
0004                 INTEGER*4 INDX                                                       388.
0005                 DIMENSION INVOLT(10)                                                 389.
0006                 COMMON/PRINT/NPRNT1,NPRNT2                                           390.
0007                 COMMCN/CCST/RUCST1(20),RUCST2(20),KFACT(10)                          391.
0008                 CCMMON/CCNST/BR,DT,DRA(65),NCYCLE,MG                                 392.
0009                 INTEGER*4 R,J,I,RF,NCYCLE                                            393.
0010                 COMMON/INTER5/MNRNOR(10),EJOT1(10),EXPO(10),CFUNCT                   394.
                    1            ,MOCST(10),IDEFMN(10),RESMN1(10)                         395.
0011                  COMMON/TWO/MECST1(20),PILE(20),PILE1(20),CPILT1(20),MNRNR1(10)     396.
                    1  ,PILFT1(20),MNCAP(110,10),MJOT(10)                                 397.
0012                 COMMON/INTER/FMG,TOPTM1,AGEPT(65),AGEPT1(65)                         398.
                    1            ,TCPT,POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)               399.
0013                 COMMON/KDATA/K1(20),K2(20),K3(20),K4(20),K5(20),FLGDAT(18,4)         400.
0014                 COMMON/INTER8/RC,CPILE(20),CAPVL(10),OUTMAT(100,40),MPRK(17),        401.
                    1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,TMEASO(15),SCAMSO      402.
0015                 COMMON/INTER7/CMEAS(15),UPPER                                        403.
0016                 CCMMON/CHAR/CJK1(6,10),CJK2(6,10),CJK3(6,10),CJK4(6,10),             404.
                    1             C1(6),C2(6),C3(6),C4(6),JC(10),ZIP                      405.
0017                 CCMMON/CAPDAT/CAPUSE(10),CAPGRO(10),REDIV(20)                        406.
0018                 DIMENSION RSOR(10),ECST(20),MECST(20),MNNORM(10)                     407.
0019                 DIMENSION STCK1(20),CAPGR1(10),KOUT(10),VAL(20)                      408.
0020                 DIMENSION XUTIL(10,20),XUTILT(20,10)                                 409.
0021                 REAL*8 TITLE(10,2)                                                   410.
0022                 DATA TITLE/'1       E','2 TRANSP','3        ','4  DEFEN',            411.
                    1  '5        ','6  HVY P','7  LGT P','8      CO','9    AGR',          412.
                    2  '10    MO','DUCATION','ORTATION',' HEALTH','SF&OTHER',             413.
                    3  ' WELFARE','OLLUTING','OLLUTING','MMERCIAL','ICULTURE',            414.
                    4  'ME & REC'/                                                        415.
0023                 REAL*8 HEADG(20,2)                                                   416.
0024                 DATA HEADG/ ' 1       ',' 2       ',' 3     L',' 4       ',          417.
                    1  ' 5       ',' 6   TRA',' 7       ',' 8       ',' 9   ELE',         418.
                    2  '10       ','11       ','12       ','13       ','14    UR',        419.
                    3  '15 SUBUR','16   ARA','17       ','18    MO','19     A',           420.
                    4'20   WAT','    IRON','  COPPER','EAD,ZINC',' MERCURY',' SILVER',   421.
                    5  'CE METAL','    COAL','     OIL','CTRICITY','        ',            422.
                    6  '  LUMBER','    FOOD','        ','BAN LAND','BAN LAND',            423.
                    7  'BLE LAND','        ','RK UNITS','IR UNITS','ER UNITS'/            424.
               C**                                                                        425.
               C**   STOCKPILE(WORK UNITS)=POPULATION OF PAID WORKERS                     426.
0025                 PILE(18)=POPKT(1,5)+POPKT(2,5)+ POPKT(3,5) + POPKT(4,5)              427.
               C**                                                                        428.
               C**   INVST IS AMOUNT OF INVESTMENT AVAILABLE                              429.
               C**   MNNORM IS SUM OF THIS CYCLE & DEFERRED LAST CYCLE CAPITAL            430.
               C**       MAINTENANCE (%): J IS CODE OF OUTPUT COMPONENT                   431.
0026                 DO 10 J= 1,10                                                        432.
0027              5  INVST(J)  = INVST1(J) * ( 1 + RGJ(J) * 0.01)                         433.
0028             10  MNNORM(J) = MNRNOR(J) +  100*(IDEFMN(J)/INVST(J))                    434.
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FORTRAN IV G LEVEL  21                 STEP2              DATE = 73311          21/32/01              PAGE 0002
                C**   STORE THE VALUE OF INVST IN INVST1 FCR NEXT CYCLE                                   438.
 0029                  DO 11 J=1,10                                                                        439.
 0030             11   INVST1(J) = INVST(J)                                                                440.
                C**                                                                                        441.
                C**   MAINR IS MAINT RATE (%) TO REPAIR ENVIRONMENTAL MEDIA                                442.
                C**   MAINT IS TOTAL MAINT RATE (%)=MNNORM+MAINR+CAPITAL EXPANSION COSTS 443.
                C**   CAPITAL EXPANSICN COSTS ARE FINANCED OVER 10 YEARS (SEE 45-74)                       444.
 0031                 DO 30  J= 1,10                                                                       445.
 0032                 MAINR(J) =  QCLT(J)*(JO(J) - 1000.00)/JO(J)                                          446.
 0033                 IF (MAINR(J).LT.0.0)  MAINR(J)=0.0                                                   447.
 0034                 MAINT(J) = MNNORM(J)+ MAINR(J) + (100*(MNCAP(NCYCLE,J)/INVST(J)))  448.
                C**                                                                                        449.
                C**   INVOUT IS FUNDS FCR COMPONENT PRODUCTION                                             450.
 0035             30  INVOUT(J) = INVST(J)/(1 + MAINT(J) * 0.01)                                           451.
                C**   STORE PRIV, PUB PRCD GROWTH IN SUMMARY TABLE                                         452.
                C**   GROWTH MEASURED IN TERMS OF PRODUCTION GROWTH                                        453.
 0036                 PURNUM=0.0                                                                           454.
 0037                 PRINUM=0.0                                                                           455.
 0038                 IF (NCYCLE.GT.1) GO TO 20                                                            456.
 0039                 DO 21 R=1,20                                                                         457.
 0040                 RUCST2(R)=RUCST1(R)                                                                  458.
 0041             21  MECST1(R)=RUCST1(R)                                                                  459.
 0042                 PRIDIV=0.0                                                                           460.
 0043                 PUBDIV=0.0                                                                           461.
 0044                 DO 22 J=1,10                                                                         462.
 0045                 IF (J.GE.6) GO TO 24                                                                 463.
 0046                 IF (J.EQ.4) GO TO 22                                                                 464.
 0047                 PUBDIV=PUBDIV+INVCUT(J)                                                              465.
 0048                 GO TO 22                                                                             466.
 0049             24  PRIDIV=PRIDIV+INVOUT(J)                                                              467.
 0050             22  CCNTINUE                                                                             468.
 0051             20  DO 26 J=1,10                                                                         469.
 0052                 IF (J.GE.6) GO TO 28                                                                 470.
 0053                 IF (J.EQ.4) GO TO 18                                                                 471.
 0054                 PUBNUM=PUBNUM+INVOUT(J)                                                              472.
 0055                 GO TO 18                                                                             473.
 0056             28  PRINUM=PRINUM+INVCUT(J)                                                              474.
 0057             18  CONTINUE                                                                             475.
 0058             26  SUMMAT(NCYCLE,3)=PUBNUM/PUBDIV                                                       476.
 0059                 SUMMAT(NCYCLE,4)=PRINUM/PRIDIV                                                       477.
                C**                                                                                        478.
 0060                 DO 40 R=1,20                                                                         479.
                C**   TEST MAINTAINS CCST AT NOT LOWER THAN LAST YEAR (BUT SEE STEP # 8) 480.
 0061                 IF (RUCST2(R).GT.RUCST1(R)) RUCST2(R)=RUCST1(R)                                      481.
                C**   THIS YEAR'S COST ESTIMATE BY LINEAR PROJECTION                                       482.
 0062             40  RUCST(R)  = 2* RUCST1(R) - RUCST2(R)                                                 483.
                C**                                                                                        484.
                C**   CALCULATE FOR EACH COMPONENT THE EST COST FOR ONE OUTPUT UNIT                        485.
                C**                                                                                        486.
                C**   UTIL(J,R) IS MATRIX OF ACTIVE I/O PRODUCTION FUNCTIONS                               487.
 0063                  DO 41 J=1,10                                                                        488.
 0064                  DO 41 R=1,20                                                                        489.
 0065             41   XUTIL(J,R)=UTIL(J,R)                                                                490.
 0066                 CALL MATMPY (XLTIL,RUCST,OCST,10,20)                                                 491.
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                C**                                                                 492.
                C**   JOT(J) IS SCHECULED OUTPUT UNITS FOR COMPCNENT                493.
                C**   (.001*KFACT) SCALES UNIT COSTS TO TRUE COMPONENT COSTS (SETS  494.
                C**       OTHER PRODLCTION COSTS AS MULTIPLIER CF RESOURCE COSTS)   495.
                C**    CALCULATE KFACT FOR NCYCLE = 1                               496.
0067                  IF (NCYCLE.NE.1) GC TO 47                                     497.
0068                  DO 48 J=1,10                                                  498.
0069                  KOUT(J)=1000.0 * CCST(J)                                      499.
0070               48 KFACT(J)=INVOUT(J)/(0.001*KCUT(J))                            500.
0071               47 DO 42 J=1,10                                                  501.
0072                  KOUT(J)=INVOUT(J)/(0.001*KFACT(J))                            502.
0073               42 JOT(J)=KCUT(J)/CCST(J)                                        503.
                C**                                                                 504.
                C**   TRANSPOSING UTIL AND SCALING TO SINGLE UNIT VALUES            505.
0074                  DO 46 J=1,10                                                  506.
0075                  DO 46 R=1,20                                                  507.
0076                  UTILT(R,J)=UTIL(J,R)                                          508.
0077               46 XUTILT(R,J)=UTILT(R,J) * 0.001                                509.
                C**                                                                 510.
                C**   RESOR(20) IS THE RESOURCE REQUIREMENTS FOR EACH CYCLE         511.
0078                  CALL MATMPY (XUTILT,JOT,RESOR,20,10)                          512.
                C**   DEVELOP RESOURCE SUMMARY DATA                                 513.
0079                  IF (NCYCLE.GT.1) GO TO 480                                    514.
0080                  DO 482 RR=1,20                                                515.
0081              482 REDIV(RR)=RESOR(RR)                                           516.
0082              480 CONTINUE                                                      517.
0083                  TEMP=0.0                                                      518.
0084                  DO 484 RR=1,6                                                 519.
0085              484 TEMP=TEMP+(RESCR(RR)/REDIV(RR))                               520.
0086                  SUMMAT(NCYCLE,6)=TEMP/6                                       521.
0087                  TEMP=0.0                                                      522.
0088                  DO 486 RR=7,9                                                 523.
0089              486 TEMP=TEMP+(RESCR(RR)/REDIV(RR))                               524.
0090                  SUMMAT(NCYCLE,7)=TEMP/3                                       525.
0091                  TEMP=0.0                                                      526.
0092                  DO 488 RR=11,12                                               527.
0093              488 TEMP=TEMP+(RESCR(RR)/REDIV(RR))                               528.
0094                  DO 490 RR=14,16                                               529.
0095              490 TEMP=TEMP+(RESCR(RR)/REDIV(RR))                               530.
0096                  SUMMAT(NCYCLE,8)=TEMP/5                                       531.
0097                  TEMP=0.0                                                      532.
0098                  SUMMAT(NCYCLE,9)=RESCR(18)/REDIV(18)                          533.
0099                  DO 492 RR=19,20                                               534.
0100              492 TEMP=TEMP+(RESCR(RR)/REDIV(RR))                               535.
0101                  SUMMAT(NCYCLE,10)=TEMP/2                                      536.
                C**                                                                 537.
                C**                                                                 539.
                C**   STDEP(20) IS THE STOCK DEPLETION LEVEL CF EACH RESOURCE       540.
0102                  CTR=1.0                                                       541.
0103                  DO 60 R=1,20                                                  542.
0104                  IF (PILE(R).EQ.0.0) GO TO 59                                  543.
                C**   END OF CYCLE RESOURCE STOCK LEVEL IS ESTCK(% OF PILE(R))      544.
0105                  ESTCK(R) = STDEP(R)+(RESOR(R)/PILE(R))*(1/(1+REREC(R)))       545.
0106                  IF (R.EQ.11.OR.R.EQ.12) GO TO 53                              546.
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      GO TO 54
C**   INCREASE AGRI BY ANNUAL PROD
   53 ESTCK(11)=ESTCK(11)-0.00005*JOT(9)
      IF (FSTCK(11).LT.0.0) ESTCK(11)=0.0
      IF (ESTCK(12).LT.0.001*JOT(9)) GO TO 52
      ESTCK(12)=ESTCK(12)-.00143*JOT(9)
       GO TO 54
   52 PILE(12) =  10.0*MJOT(9)
      ESTCK(12) = 0.0
C**   ESTCK(18) CAN BE > 1.0; EXTENDED WORK WEEK (BUT SEE AFTER 74)
      IF (R.EQ.18) GC TC 59
   54 TEMP=(ESTCK(R)-1.0)*PILE(R)
      IF (ESTCK(R).LE.1.0) GO TO 59
C**   NEED ONE TIME IMPCPT OF RESOURCE DUE TO SCHEDULED PRODUCTION;
C**         NEXT CYCLE COSTS WILL ADJUST TO ELIMINATE IMPORTS
      TEMP=(ESTCK(R)-1.0)*PILE(R)
      ESTCK(R)=0.999
   59 CONTINUE
C**    DETERMINE IF STOCK LEVELS ARE CRITICAL; FLAGR(R)=1.0
       DO 64 I=1,4
      IF (STDEP(R).LE.FLGDAT(R,I).AND.FLGDAT(R,I).LE.ESTCK(R)) GO TO 65
       IF (ESTCK(R).GE.0.985) GO TO 65
   64 CONTINUE
      FLAGR(R)=0.0
      GO TO 60
   65 FLAGR(R)=1.0
   60 CONTINUE
C**   FLAGR(20) ARE STOCK DEPLETION FLAGS OF EACH RESOURCE
C**   ESTCK(20) ARE THE NEW STOCK DEPLETION LEVELS OF EACH RESOURCE
C**
C**   CALCULATE RESOURCE UNIT COSTS - ECST(R),MECST(R),MECSTR(R)
C**    MECST IS THE MAX VALUE, ECST IS THE MEAN VALUE
C**    ECST(R),MECST(R) ARE PURCHASE COSTS;ECSTR(R),MECSTR(R) ARE COSTS
C**          TO "MINE" ONE UNIT
       DO 70 R=1,20
      TEMP=1.0
      IF (R.EQ.13) GC TO 415
      IF (R.NE.18) GC TC 413
      IF (ESTCK(18).LE.0.95) GO TO 415
      IF (ESTCK(18).GE.0.999)  ESTCK(18)=0.999
      TEMP=1.0+0.6*((ESTCK(18)-0.92)/0.08)**2
      GO TO 415
  413 CONTINUE
C**   IF STOCK LOW, RAPIDLY ESCALATE PRICE EXCEPT FOR CAPITAL,WORK UNITS
      IF (ESTCK(R).LE.0.0)  ESTCK(R)=0.000001
      IF (R.EQ.12.OR.R.EQ.14.OR.R.EQ.15.OR.R.EQ.16) GO TO 417
      IF (ESTCK(R).GT.0.9) TEMP=(0.1/(1.0-ESTCK(R)))**3
      GO TO 415
  417 IF (ESTCK(R).GE.0.9) TEMP=(0.1/(1.0-ESTCK(R)))
  415 MECST(R) =0.00001*( K1(R) + (K2(R) * (ESTCK(R)**K3(R))))*TEMP
       ECST(R)  = 0.5 * (MECST(R)+MECST1(R))
      IF (ESTCK(R).GE.0.9) ECST(R)=MECST(R)
C**   REREC IS RATIO OF UNITS RECYCLED TO UNITS MINED,SET AS FUNCTION
C**      OF STOCK USED
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0146            RERFC(R)=K4(R)+K5(R)*(ESTCK(R)**2)
0147            ECSTR(R)=ECST(R)/(1+REREC(R))                                         601.
0148            MECSTR(R) = MECST(R)/(1+REREC(R))                                     602.
0149            IF (ECSTR(R).LT.RUCST1(R)) ECSTR(R)=RUCST1(R)                         603.
0150            RUCST(R)=ECSTR(R)                                                     604.
          C**                                                                         605.
          C**   VAL(R) IS REMAINING AMOUNT OF STOCK PILE                              606.
0151            VAL(R) = PILE(R) * (1 - ESTCK(R))                                     607.
0152         70 MECST1(R)=MECST(R)                                                    608.
0153            DO 45 R=1,20                                                          609.
0154            RUCST2(R)=RUCST1(R)                                                   610.
0155         45 RUCST1(R)=RUCST(R)                                                    611.
          C**   CALCULATE CAPITAL EXPANSION COSTS IF OUTPUT PASSED MAXIMUM            612.
          C**       PLANT CAPACITY. ALLOCATE COSTS OVER NEXT 10 YEARS                 613.
0156            DO 74 J=1,10                                                          614.
0157            JO(J)=JOT(J)                                                          615.
0158            IF (JOT(J).LE.MJOT(J)) GO TO 74                                       616.
          C**   CAPITAL EXPANSION OF J EQUALS TEMP; NEW CAPITAL LEVEL IS MJOT(J)      617.
0159            TEMP=JOT(J)-MJOT(J)                                                   618.
0160            MJOT(J)=JOT(J)                                                        619.
          C**   CAPITAL EXPANSION COST/YEAR IS TEMP                                   620.
0161            TEMP=TEMP*CAPVL(J)*0.1                                                621.
0162            DO 72 I=1,10                                                          622.
0163            K=NCYCLE+I                                                            623.
0164         72 MNCAP(K,J)=MNCAP(K,J)+TEMP                                            624.
0165         74 CONTINUE                                                              625.
          C**                                                                         626.
          C**   DETERMINE USAGE OF EXISTANT FACILITIES                                627.
0166            CTR=1.0                                                               628.
0167            DO 76 J=1,10                                                          629.
0168            CAPUSE(J)=(JOT(J)/MJOT(J))*100.0                                      630.
0169            TEMP=(ALOG(MJOT(J))-ALOG(1000.0))/NCYCLE                              631.
0170            CAPGRO(J)=EXP(TEMP)                                                   632.
0171         76 CONTINUE                                                              633.
0172            DO 310 J=1,10                                                         634.
0173        310 CAPGR1(J)=100*(CAPGRO(J)-1.0)                                         635.
0174            DO 312 R=1,20                                                         636.
0175        312 STCK1(R)=ESTCK(R)*100                                                 637.
          C**                                                                         638.
          C**   OUTPUT STATEMENTS                                                     639.
0176            IF (NPRNT1.NE.1.0) GO TO 107                                          640.
0177            WRITE(6,300)                                                          641.
0178        300 FORMAT(1H0,T39,'** COMPONENT OPERATING DATA  **',//,                  642.
               1 T13,'COMPONENT',T34,'OPERATING',T46,'MAINT.',T56,                    643.
               2 'PRODUCTION',T70,'OUTPUT',T80,'CAPITAL',T90,                         644.
               3 'ANNUAL %',/,T10,'NO.',T20,'NAME',T32,'FUNDS(1000$)',                645.
               4 T46,'COST(%)',T55,'FUNDS(1000$)',T80,'% USED',T90,                   646.
               5 'EXPANSION')                                                         647.
0179            DO 370 I=1,10                                                         648.
0180            WRITE(6,372) (TITLE(I,J),J=1,2),INVST(I),MAINT(I),INVOUT(I),          649.
               1 JOT(I),CAPUSE(I),CAPGR1(I)                                           650.
0181        372 FORMAT(T10,A8,A8,T32,F11.3,3X,F6.2,3X,F11.3,3X,F7.1,                  651.
               1    5X,F5.1,5X,F6.2)                                                  652.
0182        370 CONTINUE                                                              653.
                                                                                      654.
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FORTRAN IV G LEVEL  21                STEP2             DATE = 73311        21/32/01              PAGE 0006
 0183              WRITE(6,316)
 0184          316 FORMAT(1H0,T37,'** RESOURCE UTILIZATION DATA **'//,T14,'RESOURCE', 655.
                  1  T34,'UTILIZATION',T53,'REMAINING',T65,'RFCYCLE',T75,              656.
                  2  'THIS CYCLE',/,T10,'NO.',T20,'NAME',T31,'USED IN YEAR   % USED', 657.
                  3  T53,'STOCKPILE',T66,'RATIC',T75,'UNIT CCST')                      658.
 0185              DO 340 I=1,20                                                        659.
 0186              WRITE(6,342) (HEADG(I,J),J=1,2),RESCR(I),STCK1(I),VAL(I),            660.
                  1  REREC(I),RUC ST(I)                                                 661.
 0187          342 FORMAT(T10,A8,A8,T32,F9.2,3X,F6.2,3X,F9.2,4X,F5.2,3X,F11.8)          662.
 0188          340 CONTINUE                                                             663.
 0189          107 RETURN                                                               664.
 0190              END                                                                  665.
                                                                                        666.
```

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FORTRAN IV G LEVEL  21                MATMPY            DATE = 73311        21/32/01              PAGE 0001
 0001                SUBROUTINE MATPFY (XMAT,VEC,RVEC,I,J)
 0002                IMPLICIT REAL*4 (A-Z)                                              667.
               C**   MULTIPLIES A MATRIX WITH A VECTOR OF VARIABLE DIMENSIONS           668.
 0003                INTEGER*4 I,J,IRCW,ICCL,M,N                                        669.
 0004                DIMENSION XMAT(I,J),VEC(J),RVEC(I)                                 670.
 0005                IROW=I                                                             671.
 0006                ICOL=J                                                             672.
 0007                REST=0.0                                                           673.
 0008                DO 10 M=1,IRCW                                                     674.
 0009                DO 10 N=1,ICCL                                                     675.
 0010                RES  =  XMAT(M,N) * VEC(N)                                         676.
 0011                REST = REST + RES                                                  677.
 0012                IF (N.EQ.ICOL) RVEC(M) = REST                                      678.
 0013          10    IF (N.EQ.ICOL) REST = 0.0                                          679.
 0014                RETURN                                                             680.
 0015                END                                                                681.
                                                                                        682.
```

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FORTRAN IV G LEVEL  21                STEP3              DATE = 73311        21/32/01              PAGE 0001

0001                SUBRCUTINE STEP3                                                          683.
            C**                                                                               684.
0002                IMPLICIT REAL*4 (A-Z)                                                     685.
0003                COMMCN/INTER2/PGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOR(20),             686.
                   1           ESTCK(20),RSORT(10),FSORT1(10),STDEP(20),RUCST(20),            687.
                   2           PAINT(10),OCST(10),ECST(20),REREC(20),ECSTR(20),               688.
                   3        FLAGR(20),MECSTR(20),INDX,INVST1(10),INVST(10),JOT(10),           689.
                   4   UTIL(10,20),UTILT(20,10)                                               690.
0004                INTEGER*4 INDX                                                            691.
0005                INTEGER*4 I,J,K,MDX                                                       692.
0006                COMMON/PRINT/NPRNT1,NPRNT2                                                693.
0007                COMMON/INTER3/CNJ(15,10),DN(15),THEAS(15),DNJT1(15,10),CCUNT1(15),        694.
                   1     MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                            695.
            C**     EVALUATING VALUES,RESILIENCY & ADJUSTMENTS IF REQD FOR EACH               696.
            C**       NTH MEASURE, WHERE N=15, AS THERE ARE 15 MEASURES                       697.
0008                DIMENSION DEL(15,10),DNJ(15,10),MCOUNT(10),MDNJ(10),                      698.
                   1        COUNT(15),MAXN(10)                                                699.
0009                COMMCN/INTER/FPG,TCPTM1,AGEPT(65),AGEPT1(65),TCPT,                        700.
                   1          POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)                            701.
            C**                                                                               702.
            C**     INITIALIZE STATE INDICATORS                                               703.
0010                DO 11 N=1,15                                                              704.
0011             11 COUNT(N)=0.0                                                              705.
0012                DO 12 J=1,10                                                              706.
0013                MCOUNT(J)=0.0                                                             707.
0014                MDNJ(J)=0.0                                                               708.
0015             12 MAXN(J)=0.0                                                               709.
0016                POINT=0.0                                                                 710.
0017                DO 15 J=1,6                                                               711.
0018             15 POP(J)   =  POPKT(1,J) + POPKT(2,J) + POPKT(3,J) + POPKT(4,J)             712.
0019                POP(7)   =  TOPT                                                          713.
            C**                                                                               714.
            C**     LOCP TO PROCESS EACH MEASURE IN TURN (TO 1000)                            715.
0020                PPP=1.0                                                                   716.
0021                DO 1000 N=1,15                                                            717.
0022                IF (N.EQ.12) GC TO 400                                                    718.
0023                SUM=0.0                                                                   719.
            C**                                                                               720.
            C**     CALCULATE NUMERATCR CF MEASURE                                            721.
0024                DO 10 J=1,10                                                              722.
0025                IF (JOT(J).LE.0.0) JOT(J)=2.0                                             723.
0026                MULT  =  CNJ(N,J) * JOT(J)                                                724.
0027             10 SUM = SUM + (MLLT * 0.1)                                                  725.
            C**     SELECT AFFECTED PCPULATION                                                726.
0028                INDX = DN(N)                                                              727.
0029                XX=0.0                                                                    728.
            C**     CALCULATE MEASLRE VALUE                                                   729.
0030                MEAS(N)  =( SUM)/PCP(INDX)                                                730.
            C**                                                                               731.
            C**     CALCULATE RESIL: IF < 0.0 NEED OUTPUT ADJUSTMENTS                         732.
0031                RESIL(N)  = (MEAS(N) - THEAS(N))/THEAS(N)                                 733.
0032                IF (RESIL(N).LE.2.0) GO TO 16                                             734.
            C**     THEAS(N) IS THE THRESHOLD VALUE                                           735.
            C**                                                                               736.
```

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FORTRAN IV G LEVEL  21                STEP3               DATE ⸗ 73311          21/32/01              PAGE 0002
            C**   IF RESIL >= 0.C OUTPUTS O.K.,SET DEMANDS TC 0.0 & GO TC 1000             737.
 0033          16 IF(RESIL(N).GE.0.0) GO TO 20                                             738.
            C**   IF RESIL < 0.0: NEED ADJUSTMENTS                                         738.
 0034             GO TO 30                                                                 739.
 0035          20 DC 25 J=1,10                                                             740.
 0036             DEL(N,J)= 0.0                                                            741.
 0037          25 DNJ(N,J)= 0.0                                                            742.
 0038             COUNT(N)= 0.0                                                            743.
 0039             GO TO 1000                                                               744.
            C**                                                                            745.
            C**   SET RESIL ADJUSTMENTS FOR EACH APPRCPRIATE J                             746.
 0040          30 POINT=1.0                                                                747.
 0041             DC 40 J=1,10                                                             748.
            C**   IF CNJ=0.0 THEN COMPCNENT CUTPUT DEMAND =0.0 (J NCT IN MEAS)             749.
 0042             IF (CNJ(N,J).EC.0.0) DEL(N,J)=0.0                                        750.
 0043             IF (CNJ(N,J).EC.0.0) GO TO 40                                            751.
            C**   OUTPUT DEMAND SCALED TO J'S SHARE CF SETTING MEASURE VALUE               752.
 0044             DEL(N,J)=(1/ CNJ(N,J)) *(TMEAS(N) - MEAS(N)) * POP(INDX)                 753.
            C**   DNJT1 IS CUMULATIVE NEED SINCF RESIL LAST WAS >=0.0                      754.
 0045          40 DNJ(N,J)= DNJT1(N,J) + DEL(N,J)                                          755.
            C**   COUNT IS YEARS SINCE RESIL LAST WAS >=0.0                                756.
 0046             COUNT(N)   = CCUNT1(N) + 1                                               757.
 0047        1000 CONTINUE                                                                 758.
 0048         400 IF (NPRNT1.NE.1.0) GC TO 119                                             759.
 0049             WRITE(6,111)                                                             760.
 0050         111 FORMAT(1H0,T7,'** SATISFACTION OF DEMANDS **',//,                        761.
                 1  T6,'MEASURE',T17,'PRESENT',T29,'PRESENT',/,                            762.
                 2  T7,'NUMBER',T18,'VALUE',T27,'RESILIENCE')                              763.
 0051             DO 112 N=1,12                                                            764.
 0052         112 WRITE(6,114) N,MEAS(N),RESIL(N)                                          765.
 0053         114 FORMAT(6X,I4,5X,F8.4,4X,F8.4)                                            766.
 0054         119 CONTINUE                                                                 767.
            C**                                                                            768.
            C**   END OF MEASURES CALCULATIONS                                             769.
            C**                                                                            770.
            C**   MAXIMUM OUTPUT ADJUSTMENT FOR EACH OUTPUT SECTCR J                       771.
            C**   DUE TO ADDITIONAL DEMANDS PLACED BY MEASURES WITH RESIL < 0.0            772.
 0055             IF (NPRNT1.NE.1.0) GC TO 504                                             773.
 0056              WRITE(6,503)                                                            774.
 0057         503 FORMAT(1H0,10X,'****ADJUSTMENTS  OF  SYSTEM****',///)                    775.
            C**   IF NO RESIL < 0.0  SKIP TO STATEMENT 60                                  776.
 0058         504 IF (POINT.EQ.0.0) GO TO 70                                               777.
            C**                                                                            778.
            C**   FOR EACH J, FINC THE MAX OUTPUT DEMAND  (DELMAX) AND ITS                 779.
            C**     MEASURE NO(N)                                                          780.
 0059             DC 60 J=1,10                                                             781.
 0060             DELMAX = DEL(1,J)                                                        782.
 0061             DO 50 N=1,15                                                             783.
 0062             IF (N.EQ.12) GC TC 55                                                    784.
 0063             IF (DEL(N,J).GT.DELMAX)  DELMAX=DEL(N,J)                                 785.
 0064             IF (DEL(N,J).GT.DELMAX)  MAXN(J)=N                                       786.
 0065          50 CONTINUE                                                                 787.
            C**                                                                            788.
            C**   SET PARAMETERS FCR MAXIMUM DEMAND LEVELS                                 790.
```

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FORTRAN IV G LEVEL  21                STEP3              DATE = 73311        21/32/01             PAGE 0003
 0066           55  MDEL(J) = DELMAX                                                       791.
 0067               MDX = MAXN(J)                                                          792.
 0068               MDNJ(J) =  DNJ(MDX,J)                                                  793.
 0069               MCOUNT(J)  =  CCUNT(MDX)                                               794.
 0070           60  CONTINUE                                                               795.
 0071           70  CONTINUE                                                               796.
              C**                                                                          797.
              C**   PREPARATICN FOR NEXT CYCLE                                             798.
 0072               DO 90 N=1,15                                                           799.
 0073               DO 80 J=1,10                                                           800.
 0074           80  DNJT1(N,J)  = DNJ(N,J)                                                 801.
 0075           90  COUNT1(N)  = CCUNT(N)                                                  802.
 0076           99  RETURN                                                                 803.
 0077               END                                                                    804.
```

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FORTRAN IV G LEVEL  21                STEP4              DATE = 73311         21/32/01              PAGE 0001

 0001                SUBROUTINE STEP4                                                        805.
 0002               IMPLICIT REAL*4 (A-Z)                                                    806.
            C**      ADJUSTS RESOURCE USAGE DUE TO SUBSTITUTION WITHIN THE AREA              807.
            C**                                                                              808.
 0003               CCMMCN/INTER2/RGJ(10),QULT(10),GOLT1(10),MAINR(10),RESOR(20),            809.
              1  ESTCK(20), RSCRT(10),RSORT1(10),STDEP(20),RUCST(20),MAINT(10),           810.
              C OCST(10),ECSTR(20),REREC(20),RECST(20),FLAGR(20),MECSTR(20),INDX,         811,
              2  INVST1(10),INVST(10),JOT(10),UTIL(10,20),UTILT(20,10)                     812.
 0004               INTEGER*4 INDX,IT1,NCYCLE,K4,K2,LST                                     813.
 0005               IT1=5                                                                    814.
 0006                INTEGER*4 R,RF,M,N,K,IV,MARK,J,IRN,LL,KCCL,                             815.
              1              IDX,LC,K1,II,IT                                                 816.
 0C07                REAL*4 INVST,INVST1                                                     817.
 0008                DIMENSION LSTST(20),LPST(20),SCST(10),FPT(50),MARK(10)                  818.
 0009               COMMON/CONST/BR,DT,DRA(65),NCYCLE,MG                                     819.
 0010               COMMON/PRINT/NFRNT1,NPRNT2                                               820.
 0011               COMMON/INTER8/RC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),            821.
              1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,THEASO(15),SCAMSO              822.
 0012                COMMON/TWO/MECST1(20),PILE(20),PILE1(20),CPILT1(20),MNRNR1(10)          823.
              1  ,PILET1(20),MNCAP(110,10),MJOT(10)                                        824.
 0013               COMMON/INTER4/SUBCAT(10,13),ORES(10,20),ROCST(10),SUBMAT(1000),          825.
              1   ICTR,SUBPIL(900),JCTR                                                    826.
 0014               COMMON/TWORK/WORK(20)                                                    827.
 0015               INTEGER*4 ICTR,JCTR,K3,LP,LSTST                                          828.
 0016               CTRT=1.0                                                                 829.
            C**                                                                              830.
 0017               IF (NPRNT2.NE.1.0) GC TO 200                                             831.
 0018               WRITE(6,15)                                                              832.
 0019         15    FORMAT(3X,'**RESCURCE ADJUSTMENTS**',/)                                  833.
            C**                                                                              834.
            C**     LOOP 1000 CHECKS FOR EACH R IF SUBSTITUTION IS CALLED FOR AND            835.
            C**     EXISTANT; EACH TEST IS LABELLED                                          836.
 0020        200     DO 1000 R=1,2C                                                          837.
            C**     INITIALIZE VALUES FOR EACH R                                             838.
 0021                DO 4 M=1,10                                                             839.
 0022                DO 4 N=1,20                                                             840.
 0023          4     ORES(M,N)=0.0                                                           841.
 0024                DO 5 K=1,10                                                             842.
 0025                SCST(K)=0.0                                                             843.
 0026          5    MARK(K)=0                                                                844.
 0027                POINT=0.0                                                               845.
            C**                                                                              846.
            C**     TEST 1: IF FLAGR(R)=0.0, NOT CALLED FOR THIS CYCLE: GO TO 1000           847.
 0028                IF (FLAGR(R).EQ.0.0) GO TO 1000                                         848.
            C**      SEARCHING FOR SUBSTITUTION VECTORS, MARK(K) STORES THE INDEX            849.
 0029               K=1                                                                      850.
            C**                                                                              851.
            C**     TEST 2: IF SUBSTITUTION (IV) IS FOR RESOURCE R, PUT MARK IN TEST         852.
            C**               VECTOR = TO IV POSITION & NUMBER; CTHERWISE LEAVE AS 0.0       853.
 0030               DO  10 IV=1,10                                                           854.
 0031               RR=R                                                                     855.
 0032                IF (SUBDAT(IV,1).EQ.RR) GO TO 20                                        856.
 0033               GO TO 10                                                                 857.
 0034         20     MARK(K)=K                                                               858.
 0035            10   K=K+1
               C**
               C**    TEST 3: CHECK IS CPTIONAL; NOT IN USE
               C**     CHECKING FOR FLAGS TURNED ON IN THE SUBSTITUTING RESOURCES
               C**     OF THE SUBSTITLTIN VECTORS
 0036                  DO 30 K=1,10
 0037                  IF (NCYCLE.GT.0) GO TO 53
               C**     LOOP SUPPRESSEC
 0038                  IF (MARK(K).EC.0) GC TO 50
 0039                  IV=MARK(K)
 0040                  DC  40 J=1,5
 0041                  RP=2*J+1
 0042                  IRN=SUBDAT(IV,RP)
 0043                 IF (IRN.EQ.0) CC TO 30
 0044                  IF( FLAGR(IRN).EC.0.0) GO TO 40
 0045                  MARK(K)=0
 0046           40     CONTINUE
 0047          30     CONTINUE
 0048           50     CONTINUE
 0049            53    CONTINUE
               C**
               C**
               C**     FOR ALL SUBSTITUTICNS WHICH  PASSEC THE FLAG TEST CALCULATE SCST:
               C**    SCST IS THE ONE YEAR SUBSTITUTION COST
 0050                  ICTR=0
 0051                  LST=10000.0
 0052                  LL=1
               C**
 0053                  DO 75 K=1,10
               C**    IDX TAKEN FROM TEST 2 RESIDUES
 0054                  IDX=MARK(K)
 0055                  IF (IDX.EQ.0) GC TC 70
               C**
               C**    SUBDAT CAN BE A FCRMULA FOR UP TC 5 RESOURCES (MAY INCLUDE
               C**           ORIGINAL RESOURCE)
 0056                  DO 60 J=1,5
 0057                  RP=2*J+1
               C**    IRN IS RESOURCE NUMBER TO BE SUBBED
 0058                  IRN=SUBDAT(IDX,RP)
 0059                 IF (IRN.EQ.0) GC TC 60
               C**    RP+1 IS AMOUNT TO BE SUBBED
               C**    SUM IS CCST CF J+H CCMPONENT
 0060                  SUM = SUBDAT(IDX,RP+1) * MECSTR(IRN)
               C**    SCST IS CUMULATED COSTS FOR UP TO # 5 SUBS
 0061                  SCST(LL)=SCST(LL)+SUM
 0062           60     COMP=SCST(LL)
               C**    TEST 4: IF SUB COST >= RESOURCE COST,DROP FRCM CONSIDERATION
 0063                  IF (MECSTR(P).GT.CCMP) GO TO 68
 0064                  MARK(K)=0
 0065                  SCST(LL)=0.0
 0066                  GO  TO 70
               C**    SET LST TO STATE AT LEAST ONE SUB EXISTS
 0067            68    LST=LL
               C**    ICTR IS NUMBER CF ACCEPTABLE SUBS
```

NOTE: Test 3 is dormant; if the number of resources are significantly increased, this option may be of use in reduction of computer running time.

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FORTRAN IV G LEVEL  21                  STEP4              DATE = 73311         21/32/01              PAGE 0003
 0068                ICTR=ICTR+1
 0069             70 LL=LL+1                                                                 913.
 0070             75 CONTINUE                                                                914.
             C**                                                                             915.
             C**     TEST 5: IF ICTR IS <= 1 ALL NEEDED DATA IS GATHERED                     916.
 0071                IF (ICTR.LE.1) GC TO 105                                                917.
             C**                                                                             918.
 0072                LC=1                                                                    919.
             C**                                                                             920.
             C**     STORE 5 YEAR CCST OF SUBSTITUTION FCR ALL VECTORS STILL ACTIVE          921.
 0073               DO 80 K1=1,10                                                            922.
 0074               II=MARK(K1)                                                              923.
 0075                IF (II.EQ.0) GC TO 80                                                   924.
 0076                POINT=1.0                                                               925.
             C**     SUBDAT (X,13) IS TIME TO CCMPLETE SUB IN YEARS                          926.
 0077                IT1 = SUBDAT(II,13)                                                     927.
 0078                CALL NCRMAL(IT1,FPT)                                                    928.
 0079                IT=SUBDAT(II,1)                                                         929.
             C**     90 LOOP DEVELCPS TIME SUB 5 YEAR COST INTC ORES                         931.
 0080                DO 90 K=1,5                                                             932.
 0081                SUM=MECSTR(IT)*(1-FPT(K))  + (SCST(K1)*FPT(K))                          933.
 0082          90  ORES(LC,IT) = ORES(LC,IT) + SUM                                           934.
 0083          80  LC=LC+1                                                                   935.
 0084                IF (POINT.EQ.C.0) GO TO 1000                                            936.
 0085                LST=10000                                                               937.
 0086                CMP=10000.0                                                             938.
             C**     SELECT LEAST 5 YEAR COST (MINIMUM OF ORES)                              939.
 0087                K4=1                                                                    940.
 0088                DO 110 K2=1,1C                                                          941.
 0089                IF (ORES(K2,IT).EQ.0.0) GO TO 110                                       942.
 0090                IF (ORES(K2,IT).LT.CMP)  LST=K4                                         943.
 0091               IF (ORES(K2,IT).LT.CMP) CMP=ORES(K2,IT)                                  944.
 0092         110  K4=K4+1                                                                   945.
             C**     LEAST COST CPTION IN LST IF ICTR IS .GE. 1;                             946.
             C**        ELSE NO SUB AND LST=10000.0                                          947.
 0093         105  CONTINUE                                                                  948.
 0094                IF (LST.EQ.10000) GC TO 1000                                            949.
             C**                                                                             950.
             C**     FOR SUB LST STORE THE TIME PHASED SUBS INTO SUBMAT AS (YEAR OF          951.
             C**     SUB,RESOURCE SUBBED,SUB #, FRAC OF SUB COMPLETED)                       952.
 0095                IT1=SUBDAT(LST,13)                                                      953.
 0096                CALL NCRMAL(IT1,FPT)                                                    954.
 0097                DO 900 K3=1,IT1                                                         955.
 0098                ICTR=SUBMAT(1)                                                          956.
 0099                IF (ICTR.GE.995) GC TO 910                                              957.
 0100                SUBMAT(ICTR+1) = NCYCLE + K3                                            958.
 0101                SUBMAT(ICTR+2) = R                                                      959.
 0102                SUBMAT(ICTR+3) = LST                                                    960.
 0103                SUBMAT(ICTR+4) = FPT(K3)                                                961.
 0104         900  SUBMAT(1) = ICTR + 4                                                      962.
 0105                GC TO 915                                                               963.
 0106         910  IF (NPRNT2.NE.1.0) GO TO 915                                              964.
 0107                WRITE (6,911)                                                           965.
 0108         911  FORMAT(5X,'RESCURCE SUB NCT CCMPLETED: STCRAGF OVERFLOW',/)               966.
                                                                                             967.
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0109          915  IF(R.EQ.14.OR.R.EQ.15) GO TO 914                                    968.
             C**    IF R IS NOT LAND, SUB MARK SET SO SUB CANNCT BE DCNE AGAIN         969.
0110                SUBDAT(LST,1) = SUBDAT(LST,1) * (-1.0)                             970.
0111          914  LP=NCYCLE+K3                                                        971.
             C**                                                                       972.
             C**    PRINT RESCURCE SUBSTITUTION ACTION STATEMENT                       973.
0112                IF (NPRNT2.NE.1.0) GO TO 1000                                      974.
0113                IF (CTRT.NE.1.C) GO TO 901                                         975.
0114                WRITE(6,879)                                                       976.
0115          879  FORMAT(T6,'RESCURCE',T18,'SUBS.',T27,'STOCKPILE',                   977.
                1   T41,'YEAR',/,T7,'NUMBER',T17,'NUMBER',T28,'INCREASE',              978.
                2   T38,'COMPLETED')                                                   979.
0116                CTRT=2.0                                                           980.
0117          901  WRITE(6,877) R,LST,LP                                               981.
0118          877  FORMAT(6X,I4,7X,I4,10X,'0.0',6X,I4)                                 982.
0119         1000  CONTINUE                                                            983.
             C**                                                                       984.
             C**    RESOURCE SUB LCCP CCMPLETED                                        985.
             C**                                                                       986.
             C**                                                                       987.
             C**   BEGIN CHECK TO SEE IF STOCK PILE SHOULD BE INCREASED. THIS          988.
             C**        ACTION CAN BE REPEATED AFTER PRESENT INCREASE IS DONE          989.
0120               DO 800 R=1,20                                                       990.
             C**   IF RESOURCE IS ANNUALLY RENEWABLE, GO TO 820                        991.
0121                IF (R.EQ.9.OR.R.EQ.14.OR.R.EQ.15.CR.R.EQ.16) GO TO 810             992.
             C**   IF RESOURCE IS AIR OR WATER GO TO 810                               993.
0122                IF (R.EQ.19.OR.R.EQ.20) GO TO 810                                  994.
             C**   IF R IS FARM GCODS GC TC 805                                        995.
0123                IF (R.EQ.11.OR.R.EQ.12) GO TO 805                                  996.
             C**   IF RESOURCE IS WORKERS, SKIP                                        997.
0124               IF (R.EQ.18) GC TO 800                                              998.
             C**   IF RESOURCE FLAG NOT SET, SKIP RESOURCE                             999.
0125                IF (FLAGR(R).EC.0.0) GO TO 800                                    1000.
             C**   IF AMOUNT OF EXPANSION IS 0.0, SKIP                                1001.
0126               IF (CPILE(R).LE.0.0) GO TO 800                                     1002.
             C**   IF AN INCREASE IS PRESENTLY BEING DCNE, SKIP                       1003.
0127               IF(WCRK(R).GT.C.0) GO TO 800                                       1004.
             C**                                                                      1005.
             C**   DEVELOP TIME PHASED INCREASE FOR 5 YEAR CCMPLETICN PERIOC          1006.
0128               PP=0.0                                                             1007.
0129               CALL NORMAL(5,FFT)                                                 1008.
             C**   STORE EXPANSION VALUES FOR NEXT 5 YEARS IN SUBPIL AS:              1009.
             C**      (RESOURCE,YEAR,AMCUNT ADDED)                                    1010.
0130               DO 820 K4=1,5                                                      1011.
0131               JCTR=SUBPIL(1)                                                     1012.
0132               IF (JCTR.GE.895) GO TO 830                                         1013.
0133               SUBPIL(JCTR+1) = R                                                 1014.
0134               SUBPIL(JCTR+2) = NCYCLE + K4                                       1015.
0135               SUBPIL(JCTR+3) = CPILE(R) * (FPT(K4)-PP)                           1016.
0136               PP = FPT(K4)                                                       1017.
0137         820   SUBPIL(1) = JCTR + 3                                               1018.
0138               GO TO 840                                                          1019.
0139          830  IF (NPRNT2.NE.1.0) GO TO 840                                       1020.
0140               WRITE (6,831)                                                      1021.
```

```
 0141          831  FORMAT(5X,'RESCURCE STOCKPILE NOT INCREASED: STORAGE OVERFLOW',/) 1022.
              C**   SET COUNTER AS INACTIVE FCR 5 YEARS                               1023.
 0142          840  WORK(R)=5.0                                                        1024.
 0143               LP=NCYCLE+K4                                                       1025.
              C**                                                                      1026.
              C**   PRINT RESOURCE EXPANSION ACTION STATEMENT                          1027.
 0144               IF (NPRNT2.NE.1.0) GC TO 800                                       1028.
 0145               IF (CTRT.NE.1.C) GC TO 952                                         1029.
 0146               WRITE(6,953)                                                       1030.
 0147          953 FORMAT(T6,'RESCLRCE',T18,'SUBS.',T27,'STOCKPILF',                   1031.
                  1  T41,'YEAR',/,T7,'NUMBER',T17,'NUMBER',T28,'INCREASE',            1032.
                  2  T38,'COPPLETEC')                                                  1033.
 0148               CTRT=2.0                                                           1034.
 0149          952  WRITE(6,954) R,CPILF(R),LP                                         1035.
 0150          954 FORMAT(6X,I4,8X,'0.0',7X,F6.0,6X,I4)                                1036.
 0151               GO TO 800                                                          1037.
              C**   AGRI STOCKS CAN EXPAND BASED ON FSTCK                              1038.
 0152          805  GO TO 800                                                          1039.
              C**                                                                      1040.
              C**   RENEWABLE STOCKS RESET TO LIMIT                                    1041.
 0153          810  FSTCK(R)=0.0                                                       1042.
 0154          800  CONTINUE                                                           1043.
              C**                                                                      1044.
              C**   IF MAX WORK UNITS EXCEEDED BY 1.14 CUT OUTPUT                      1045.
              C**     OF PUBLIC COMPONFNTS                                             1046.
 0155               IF (ESTCK(18).LT.(1.14*PILE(18))) GC TO 700                        1047.
 0156               TEMP=0.0                                                           1048.
              C**   CALCULATE PUBLIC WCRKERS                                           1049.
 0157               DO 710 J=1,5                                                       1050.
 0158          710  TEMP=JOT(J)*UTIL(J,18)*0.001+TEMP                                  1051.
              C**   CALCULATE OVERAGE                                                  1052.
 0159               COMP=ESTCK(18)-1.14*FILE(18)                                       1053.
              C**   REDUCE CONSUMEC OUTPUT                                             1054.
 0160               DO 720 J=1,5                                                       1055.
 0161          720  JOT(J)=JCT(J)*(TEMP-CCMP)/TEMP                                     1056.
 0162               TEMP=100.0*(TEMP-CCMP)/TEMP                                        1057.
 0163          700  CONTINUE                                                           1058.
 0164               RETURN                                                             1059.
 0165               END                                                                1060.
```

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FORTRAN IV G LEVEL  21              NORMAL             DATE = 73311          21/32/01               PAGE 0001
 0001               SUBROUTINE NORMAL(IT1,FPT)
 0002               IMPLICIT REAL*4 (A-Z)                                                    1061.
              C**   NORMALIZED CUMULATIVE NORMAL                                             1062.
              C**                                                                            1063.
 0003               INTEGER*4 II, ITO,IT1,IT,IDEL,MEW,IDEL                                   1064.
 0004               DATA A1,A2,A3,A4/0.278393,0.230389,0.000972,0.078108/                    1065.
 0005               DATA FTO,FT1/0.02275,0.97725/                                            1066.
 0006               DATA ITO/0/                                                              1067.
              C**                                                                            1068.
 0007               DIMENSION FPT(50)                                                        1069.
              C**   CALCULATING THE MEAN                                                     1070.
 0008               XMEW=(ITO+IT1)/2.0                                                       1071.
              C**   CALCULATING THE VARIANCE                                                 1072.
 0009               SIG= (IT1 - ITO)/4.0                                                     1073.
              C**                                                                            1074.
 0010               DO  100  IT=1,IT1                                                        1075.
 0011               IT = IT - 1                                                              1076.
 0012                TEMP=IT - XMEW                                                          1077.
 0013               X = ABS(TEMP)/(1.41421 * SIG)                                            1078.
 0014               X2 = X*X                                                                 1079.
 0015               X3 = X2 * X                                                              1080.
 0016               X4 = X3 * X                                                              1081.
 0017               IDEL = 1                                                                 1082.
 0018               MEW=XMEW                                                                 1083.
 0019               IF (IT.LT.MEW) IDEL = -1                                                 1084.
 0020               IT = IT+1                                                                1085.
 0021               PHI = 1 - (1/((1 + A1*X + A2*X2 + A3*X3 + A4*X4)**4))                    1086.
 0022               FT = 0.5 + ( IDEL * (PHI/2))                                             1087.
 0023               FPT(IT) = (FT - FTO)/(FT1 - FTO)                                         1088.
 0024           100 CONTINUE                                                                 1089.
 0025               II=IT1-1                                                                 1090.
 0026               DO 200 IT=1,II                                                           1091.
 0027           200 FPT(IT) = FPT(IT+1)                                                      1092.
 0028               FPT(IT1) = 1.0                                                           1093.
 0029               RETURN                                                                   1094.
 0030               END                                                                      1095.
                                                                                             1096.
```

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FORTRAN IV G LEVEL  21                STEP5              DATE = 73311          21/32/01                PAGE 0001

 0001                SUBROUTINE STEP5(S8)                                                     1097.
               C**                                                                            1098.
 0002                IMPLICIT REAL*4 (A-Z)                                                    1099.
               C**   REALLOCATE INVESTMENTS TO MEET ANTICIPATED THRESHOLDS IN THE             1100.
               C**   CYCLE                                                                    1101.
 0003                COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOR(20),            1102.
                   1        ESTCK(20),RSORT(10),RSORT1(10),STDEP(20),RUCST(20),               1103.
                   2        MAINT(10),CCST(10),ECST(20),REREC(20),ECSTR(20),FLAGR(20),        1104.
                   3      MECSTR(20),INDX,INVST1(10),INVST(10),JOT(10),UTIL(10,20),           1105.
                   4        UTILT(20,10)                                                      1106.
 0004                INTEGER*4 INDX                                                           1107.
 0005                INTEGER*4 JJ,R,J,N,J2,J3                                                 1108.
 0006                COMMON/PRINT/NFRNT1,NPRNT2                                               1109.
 0007                COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),DNJT1(15,10),CCUNT1(15),1110.
                   1      MDEL(10),RFSIL(15),POP(8),VN(15),MEAS(15)                            1111.
 0008                DIMENSION XINCST(10),SINCST(2),XUTILT(20,10)                             1112.
 0009                DIMENSION  XUTIL(10,20),XMOCST(10)                                       1113.
 0010                 DIMENSION EJCT(10),EFUND(10),XINJO(10)                                  1114.
 0011                COMMON/COST/RUCST1(20),RUCST2(20),KFACT(10)                              1115.
 0012                COMMON/INTER5/MNRNOR(10),EJOT1(10),EXPO(10),CFUNDT                       1116.
                   1             ,MCCST(10),IDEFMN(10),RESMN1(10)                             1117.
 0013                DIMENSION CST(10)                                                        1118.
               C**                                                                            1119.
 0014                 IF (NPRNT2.NE.1.0) GO TO 101                                            1120.
 0015                WRITE(6,9)                                                               1121.
 0016            9   FORMAT(1H0,T6,'SHORT TERM FUNDS ADJUSTMENTS',/)                          1122.
               C**                                                                            1123.
               C**   INITIALIZE DATA AREAS                                                    1124.
 0017          101   DO 1 J=1,10                                                              1125.
 0018                IDEFMN(J)=0.0                                                            1126.
 0019                CST(J)=0.0                                                               1127.
 0020                MOCST(J)=0.0                                                             1128.
 0021                XINCST(J)=0.0                                                            1129.
 0022                XINJO(J)=0.0                                                             1130.
 0023                EFUND(J)=0.0                                                             1131.
 0024            1   EJOT(J)=0.0                                                              1132.
 0025                EFUNDT=0.0                                                               1133.
 0026                PRP=1.0                                                                  1134.
               C**   FOR EACH OUTPUT(J) DETERMINE IF MORE OUTPUT IS DEMANDED                  1135.
               C**   (MDEL IS .GT. 0.0); OTHERWISE GO TO EXPORT ROUTINE                       1136.
 0027                DO 1000 J=1,10                                                           1137.
 0028                IF (MDEL(J).GT.0.0) GO TO 10                                             1138.
 0029                GO TO 35                                                                 1139.
               C**                                                                            1140.
               C**   CALCULATE LEVEL OF J MAINTENANCE THAT CAN BE DEFERRED                    1141.
 0030           10   IDEFMN(J)=(MNRACR(J)*INVST(J))*0.01                                      1142.
               C**   DETERMINE COST TO IMPORT GOODS TO MEET DEMAND OF J                       1143.
 0031                SUM1=0.0                                                                 1144.
 0032                DO 20 R=1,20                                                             1145.
 0033                SUM=UTIL(J,R)*MECSTR(R)                                                  1146.
 0034           20   SUM1=SUM1+SUM                                                            1147.
 0035                CST(J)=MDEL(J)*SUM1*0.001*KFACT(J)                                       1148.
               C**                                                                            1149.
               C**   DETERMINE AMT OF MAINT TO BE DEFERRED & AMOUNT OF GOODS TO BE            1150.
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                C**        IMPORTED WITH MONEY GENERATED                                      1151.
                C**     CMIN IS FRACTION OF DEMAND MET BY MAINT DEFERRAL                      1152.
  0036                  CMIN= IDEFMN(J)/CST(J)                                                1153.
  0037                  IF(CMIN.GT.1.0) CMIN=1.0                                              1154.
  0038                  JOT(J)=(CMIN*MDEL(J))+JOT(J)                                          1155.
                C**     MDEL(J) IS RESIDUE OF IMPORT DEMAND                                   1156.
  0039                  MDEL(J)=MDEL(J)*(1-CMIN)                                              1157.
                C**                                                                           1158.
                C**     XINCST IS COST TO IMPORT RESIDUE                                      1159.
  0040                  XINCST(J)=MDEL(J)*SUM1*0.001*KFACT(J)                                 1160.
                C**                                                                           1161.
                C**     SKIP EXPORT ROUTINE - ALL GOODS CONSUMED INTERNALLY FOR J             1162.
  0041                  GO TO 1000                                                            1163.
                C**                                                                           1164.
                C**     CALCULATE AMT & FUNDS OF J COMPONENT EXPORT                           1165.
                C**                                                                           1166.
  0042              35  RESMN=5.0                                                             1167.
                C**     DETERMINE MIN RESIL FOR J                                             1168.
  0043                  DO 36 N=1,15                                                          1169.
  0044                  IF (CNJ(N,J).EQ.0.0) GO TO 36                                         1170.
  0045                  IF (RESIL(N).LT.RESMN) RESMN=RESIL(N)                                 1171.
  0046              36  CONTINUE                                                              1172.
                C**                                                                           1173.
                C**     EJOT(J) IS OUTPUT UNITS OF J TO EXPORT (%)                            1174.
  0047                  EJOT(J)=EJOT1(J)*(RESMN/RESMN1(J))                                    1175.
                C**     EFUND(J) IS FUNDS GENERATED BY EXPORTS                                1176.
  0048                  EFUND(J)=EJOT(J)*.01*JOT(J)*CCST(J)*0.001*KFACT(J)*(1+.01*EXPO(J))1177.
  0049                  EJOT1(J)=EJOT(J)                                                      1178.
  0050                  RESMN1(J)=RESMN                                                       1179.
                C**     EFUNDT IS FUNDS THIS CYCLE; CFUNDT IS CUMULATED FUNDS                 1180.
  0051                  EFUNDT=EFUNDT+EFUND(J)                                                1181.
  0052                  CFUNDT=CFUNDT+EFUND(J)                                                1182.
  0053            1000  CONTINUE                                                              1183.
                C**                                                                           1184.
                C**     MAINT & EXPORT LOOP COMPLETE                                          1185.
                C**                                                                           1186.
  0054                  S8=0.0                                                                1187.
                C**     DETERMINE IF IMPORTS STILL NEEDED                                     1188.
                C**     SINCST(2) ARE FUNDS NEEDED FOR IMPORT OF PUBLIC SECTOR                1189.
                C**               GOODS; SINCST(1) FOR PRIVATE SECTOR                         1190.
  0055                  SINCST(2)=XINCST(1)+XINCST(2)+XINCST(3)+XINCST(4)+XINCST(5)           1191.
  0056                  SINCST(1)=XINCST(6)+XINCST(7)+XINCST(8)+XINCST(9)+XINCST(10)          1192.
                C**                                                                           1193.
                C**     IF NO PRIVATE SECTOR IMPORTS NEEDED CHECK PUBLIC NEEDS AT 225         1194.
  0057                  IF (SINCST(1).EQ.0.0) GO TO 225                                       1195.
                C**     IF ENOUGH FUNDS TO TOTALLY MEET PRIVATE NEEDS, GO TO 200              1196.
  0058                  IF (CFUNDT.GE.SINCST(1)) GO TO 200                                    1197.
                C**                                                                           1198.
                C**     PSEC IS FRACTION OF PRIVATE SECTOR DEMAND THAT CAN BE MET USING       1199.
                C**           ALL OF CFUNDT                                                   1200.
  0059                  PSEC=CFUNDT/SINCST(1)                                                 1201.
  0060                  CFUNDT=0.0                                                            1202.
  0061              55  J2=5                                                                  1203.
                C**                                                                           1204.
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      C**   LOOP CAN BE REACHED FROM 55 (J=5) OR AFTER 225 (J=0);
      C**          SETS GOODS IMPORT LEVELS USING ALL CFUNDT
        56  DO 60 J3=1,5
            J=J2+J3
            XINJO(J)=MDEL(J)*PSEC
      C**
      C**   UNMET REQUIREMENTS RESET: JOT(J) IS LEVEL OF GOODS CONSUMED
            MDEL(J)=MDEL(J)-XINJO(J)
        60  JOT(J)=JOT(J)+XINJO(J)
      C**   EXIT ROUTINE SINCE ALL CFUNDT IS EXHAUSTED
            S8=1.0
            GO TO  311
      C**
      C**   CFUNDT SUFFICIENT TO MEET ALL PRIVATE J DEMANDS
      C**   ALL DEMAND MDEL=0 WITH XINJO (IMPORTS) = OLD MDEL
      C**
       200  DO 220 J=6,10
            XINJO(J)=MDEL(J)
            MDEL(J)=0
      C**
      C**   JOT(J) SET TO GOODS CONSUMED, CFUNDT RESET
       220  JOT(J)=JOT(J)+XINJO(J)
            CFUNDT=CFUNDT-SINCST(1)
      C**
      C**   DETERMINE IF CFUNDT NEEDED, SUFFICIENT FOR PUBLIC SECTOR DEMANDS
       225  IF (SINCST(2).EQ.0.0) GO TO 311
      C**   IF FUNDS SUFFICIENT GO TO 300; OTHERWISE USE 56-60 LOOP WITH
      C**          NEW K EQUAL TO FRACTION OF DEMAND THAT IS MET
            IF (CFUNDT.GE.SINCST(2)) GO TO 300
            PSEC=CFUNDT/SINCST(2)
            J2=0
            GO TO 56
      C**
      C**   CFUNDT SUFFICIENT TO MEET ALL PUBLIC J DEMANDS (DONE LIKE 200-220)
       300  DO 310 J=1,5
            XINJO(J)=MDEL(J)
            MDEL(J)=0
       310  JOT(J)=JOT(J)+XINJO(J)
            CFUNDT=CFUNDT-SINCST(2)
      C**
      C**   EXIT PARAMETER S8=0.0 IF DEMANDS ARE MET; S8=1.0 IF SOME
      C**              DEMAND NOT MET
       311  CONTINUE
      C**
      C**   PRINT OUTPUT INFORMATION
            IF (NPRNT2.NE.1.0) GO TO 102
      C**   PRINT MAINT DEFERRAL ACTION STATEMENT
            WRITE(6,432)
       432  FORMAT(T6,'COMPONENT',T17,'MAINT.AMT',T30,'UNITS FROM',
           1  /,T8,'NUMBER',T18,'DEFERRED',T30,'EXPORT BAL.')
            DO 22 J=1,10
            IF (IDEFMN(J).EQ.0.0.AND.XINJO(J).EQ.0.0) GO TO 22
            WRITE(6,434) J,IDEFMN(J),XINJO(J)
        22  CONTINUE
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FORTRAN IV G LEVEL  21              STEPS              DATE = 73311          21/32/01              PAGE 0004

 0092          434 FORMAT(T8,I4,T17,F9.2,T30,F10.2)                                           1259.
 0093              WRITE (6,302) CFUNDT                                                       1260.
 3094          302 FORMAT(T6,'CUMLLATIVE EXPORT BALANCE IS',2X,F15.4,/)                       1261.
 J095          102 RETURN                                                                     1262.
 0096              END                                                                        1263.
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FORTRAN IV G LEVEL  21                  STEP6              DATE = 73311          21/32/01                PAGF 0001

0001                SUBROUTINE STEP6(PSUM1,PSUM2)
0002                IMPLICIT REAL*4 (A-Z)                                                     1264.
0003                COMMON/INTER2/RGJ(10),QDLT(10),QDLT1(10),MAINR(10),RESOR(20),             1265.
                  1       ESTCK(20),RSORT(10),RSORT1(10),STDEP(20),RUCST(20),                 1266.
                  2       MAINT(10),OCST(10),ECST(20),REREC(20),ECSTR(20),FLAGR(20),          1267.
                  3      MECSTR(20),INDX,INVST1(10),INVST(10),JOT(10),UTIL(10,20),            1268.
                  4       UTILT(20,10)                                                        1269.
0004                COMMON/PRINT/NFFAT1,NPRNT2                                                1270.
0005                INTEGER*4 INDX,LT,K5,PP,K4,NCYCLE                                         1271.
0006                 INTEGER*4 TEMF,J,K,K1                                                    1272.
0007                COMMON/CONST/BP,DT,DRA(65),NCYCLE,MG                                      1273.
0008                COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),DNJT1(15,10),COUNT1(15),        1274.
                  1     MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                             1275.
0009                 COMMON/INTER/FMG,TOPTM1,AGEPT(65),AGEPT1(65),TOPT,                       1276.
                  1                    POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)                   1277.
0010                 COMMON/INTER6/XUTIL(17,20),XOCST(17),MARK(17),TIME(17),CTR,              1278.
                  1  SUBIOP(1000)                                                             1279.
0011                INTEGER*4 CTR,J2,J3,LTNCY                                                 1280.
0012                COMMON/INTER5/PNRNOR(10),EJCT1(10),EXPO(10),CFUNDT                        1281.
                  1              ,MOCST(10),IDEFMN(10),RESMN1(10)                             1282.
0013                COMMON/INTER4/SUBCAT(10,13),ORES(10,20),ROCST(10),SUBMAT(1000),           1283.
                  1   ICTR,SUBPIL(900),JCTR                                                   1284.
0014                INTEGER*4 ICTR,JCTR                                                       1285.
0015                COMMON/INTER8/FC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),             1286.
                  1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,TMEASO(15),SCAMSO             1287.
0016                 DIMENSICN INVST2(10),INEED2(10),IOVER2(10),INUP2(2),IDWN2(2),            1288.
                  1   TRINS(2),DIFFS(2),DELRGJ(10),YOCST(17),XST(17)                          1289.
0017                  INTEGER*4 KK5,R,P,J,K                                                   1290.
0018                 DIMENSICN FPT(50)                                                        1291.
             C**                                                                              1292.
             C**        FIND LOWER COST I/O PROCESS                                           1293.
             C**     MOCST IS PRESENT PROCESS MAX COST; XOCST IS OTHER PROCESS                1294.
             C**          SUBSTITUTE COST                                                     1295.
0019                  CALL MATMPY(XUTIL,MECSTR,XOCST,17,20)                                   1296.
0020                  CALL MATMPY(LTIL,MECSTR,MOCST,10,20)                                    1297.
             C**                                                                              1298.
             C**     PRINT HEADER FCR LONG TERM ADJUSTMENTS                                   1299.
0021                 IF (NPRNT2.NE.1.0) GO TO 201                                             1300.
0022                 WRITE(6,8)                                                               1301.
0023             8   FORMAT(T6,'LONG TERM ADJUSTMENTS',/)                                     1302.
             C**                                                                              1303.
             C**     DO I/O SUB PROCESS CHECK FCR ALL J                                       1304.
0024           201   DO 1000 J=1,10 .                                                         1305.
             C**     INITIALIZE YOCST FOR EACH J                                              1306.
0025                 DO 500 P=1,17                                                            1307.
0026                   YOCST(P)=0.0                                                           1308.
0027                 INDX=MARK(P)                                                             1309.
             C**                                                                              1310.
             C**     IF PROCESS NOT FOR J OR IF STATUS IS NOT ALTERNATE PROCESS,              1311.
             C**        DO NOT CONSIDER (GO TO 500)                                           1312.
0028                   IF (INDX.NE.J) GC TO 500                                               1313.
0029                 IF (MBRK(P).NE.0.0) GO TO 500                                            1314.
0030                   IF (XOCST(P).GE.MOCST(J)) GO TO 500                                    1315.
             C**     SUB PROCESS TAKES TIME(P) YEARS; GET SUBPROCESS VALUES                   1316.
                                                                                              1317.
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                                                                              1318.
          C**          FROM NOFPAL                                            1319.
 0031                LT=TIME(P)                                               1320.
 0032                CALL NORMAL(LT,FPT)                                      1321.
          C**                                                                 1322.
          C**        CALCULATE 5 YEAP COST IF MARK(P)=J                       1323.
 0033                DO 100 K5=1,5                                            1324.
 0034         100    YOCST(P)=YOCST(P) + 0.2*(MOCST(J)*(1-FPT(K5))+XOCST(P)*FPT(K5))  1325.
 0035         500    CONTINUE                                                 1326.
          C**     COST OF ALL I/C CANDIDATES STORED IN YOCST; IF              1327.
          C**            YOCST=0.0, NOT A CANDIDATE                           1328.
 0036             KK5=0                                                       1329.
          C**                                                                 1330.
          C**     COMPARE YOCSTS TO COMP=MOCST(J); IF YOCST IS .LT. MOCST,    1331.
          C**            SUR WILL BE DONE                                     1332.
 0037             CCMP=MOCST(J)                                               1333.
 0038             DO 95 PP=1,17                                               1334.
 0039             IF (YOCST(PP).LE.0.0) GO TO 95                              1335.
          C**     P PASSES TEST; IN FUTURE TESTS SUR YOCST(P) FOR MOCST       1336.
 0040             IF (YOCST(PP).GE.COMP) GO TO 95                             1337.
          C**     PP IS PRESENT SUBSTITUTE I/O PROCESS                        1338.
 0041             KK5=PP                                                      1339.
 0042             COMP=YOCST(PP)                                              1340.
          C**     KK5 IS CHCSEN; IF 0 NO SUB CHOSEN                           1341.
          C**                                                                 1342.
 0043         95  CONTINUE                                                    1343.
 0044             IF (KK5.EQ.0) GC TC 1000                                    1344.
          C       WRITE(6,901)                                                1345.
          C901    FORMAT(5X,'START 900 LOOP, STEP6',/)                        1346.
          C**                                                                 1347.
          C**     STORE I/O SUB VALUES FOR LT YEARS IN SUBICP MATRIX AS       1348.
          C**         (COMPONENT,I/C LINE,VALUE DONE, YEAR)                   1350.
 0045             DO 900 K4=1,LT                                              1351.
 0046             CTR=SUBIOP(1)                                               1352.
 0047             IF (CTR.GE.995) GC TO 913                                   1353.
 0048             SUBIOP(CTR+1) = J                                           1354.
 0049             SUBIOP(CTR+2) = KK5                                         1355.
 0050             SUBIOP(CTR+3) = FPT(K4)                                     1356.
 0051             SUBIOP(CTR+4) = K4+NCYCLE                                   1357.
 0052        900  SUBIOP(1) = CTR + 4                                         1358.
 0053             GC TO 904                                                   1359.
 0054         913 IF (NPRNT2.NE.1.0) GO TO 904                                1360.
 0055             WRITE (6,914)                                               1361.
 0056        914  FORMAT(5X,'I/O SUP NCT CCMPLETED: STORAGE OVERFLOW',/)      1362.
          C**                                                                 1363.
          C**     SET MARKER AS SUBSTITUTION IN PROCESS                       1364.
          C**                                                                 1365.
          C**     PRINT I/O SUB ACTICN STATEMENT                              1366.
 0057         904 LTNCY=NCYCLE+LT                                             1367.
 0058             WRITE(6,902) J,KK5,LTNCY                                    1368.
 0059         902 FORMAT(T6,'COMPONENT',I4,T19,': NEW I/O FORMULA NO.',       1369.
                 1   I4,T46,': CCPPLETE IN YR.',I4)                           1370.
 0060             MBRK(KK5)=-1.0                                              1371.
 0061        1000  CONTINUE                                                   1372.
          C**     I/O ROUTINE COPPLETE FOR ALL J
```

```
               C**
               C**   FUNDS TRANSFER ROUTINE TO ADJUST RATES OF GROWTH
               C**
               C**   INITIALIZE DATA FCR ROUTINE
  0062                DO 907 J=1,10
  0063            907 DELRGJ(J)=0.0
  0064                INUP2(1)=0
  0065                INUP2(2)=0
  0066                IDWN2(1)=0
  0067                IDWN2(2)=0
               C**
               C**   EXTRAPOLATE FUNCS EXPECTED (INVST2) & NEEDED (INEED2) FCR J
  0068               DO 20 J=1,10
  0069               INVST2(J) =   IAVST(J)  * (1 + RGJ(J) * 0.01)
  0070                 INEED2(J) =   INVST(J) * (1 +MDEL(J)/JOT(J)) * (TOPT/TOPTK1)
               C**   IOVER2 IS ANT CF FUNDS EXPECTED OVER NEEDED (IF .LT.0, NEED FUNDS)
  0071               IOVER2(J) =  IAVST2(J) -  INFSD2(J)
               C**
               C**   INUP2(1,2) ARE CCMPONENT POSITIVE IOVER2;
               C**   IDWN2(1,2) ARE COMPONENT NEGATIVE IOVER2
               C**   J=6,10 WITH K=1, J=1,5 WITH K=2
  0072                IF (IOVER2(J).GE.0.0) GO TO 21
  0073               K=2
  0074                IF (J.GE.6) K=1
  0075               IDWN2(K)= IDWN2(K)-IOVER2(J)
  0076               GO TO 20
  0077            21 K=2
  0078                IF (J.GE.6) K=1
  0079               INUP2(K)=INUP2(K)+IOVER2(J)
               C**   EXTRAPCLATICN LCCP CCMPLETEC
               C**
  0080            20 CONTINUE
               C**
               C**   FUNDS TRANSFER FIRST INTERSECTCR (TC 99) THEN INTRASECTOR (TC 999)
  0081            34 DO 99 K= 1,2
               C**   CASH TRANSFER BETWEEN SECTCRS (TC 99)
               C**   IF IDWN2=0 NO FUNDS NEEDED; IF INUP2 .GE.ICWN2 NC INTERSECTOR
               C**          TRANSFER NEEDED
  0082                IF (IDWN2(K).EC.0.0) GO TC 99
  0083               IF (INUP2(K).LT.IDWN2(K)) GO TO 37
  0084                GO TO 99
  0085            37  IF(K.EQ.1) K1=2
  0086               IF(K.EQ.2) K1=1
               C**
               C**   FUNDS OF INTER NEEDED ARE TRINS(K)
  0087                TRINS(K) = IDWN2(K)-INUP2(K)
               C**
               C**   OTHER SECTOR HAS NC FUNDS FOR INTER
  0088               IF (INUP2(K1).LT.ICWN2(K1)) GO TO 99
               C**   DIFFS(K1) ARE FUNDS AVAILABLE FOR INTER
  0089               DIFFS(K1) = INUF2(K1)-IDWN2(K1)
               C**
               C**   IF OD.GE. T, TRINS REQUIREMENT FULLY MET
  0090               IF(DIFFS(K1).GE.TRINS(K))  GO TO 60
```

```
              C**   LOWER TRINS TO FUNDS AVAILABLE                                      1427.
 0091            85 TRINS(K)=DIFFS(K1)                                                  1428.
              C**   FUNDS ARE TRANSFERRED ON EQUAL % BASIS                              1429.
              C**   BETWEEN COMPONENTS CF SECTORS                                       1430.
              C**   INTRASECTOR WILL CCMPLETE REDISTRIBUTICN                            1431.
 0092            60 CONTINUE                                                            1432.
 0093               CCMP=0.0                                                            1433.
 0094               J2=5*(2-K)                                                          1434.
              C**   FOR RECEIVING SECTOR, INCREASE SECTION IS COMP                      1435.
 0095               DO 62 J3=1,5                                                        1436.
 0096               J=J3+J2                                                             1437.
 0097            62 COMP=COMP+INVST2(J)                                                 1438.
 0098               COMP=TRINS(K)/CCMP                                                  1439.
              C**   RESULT OF SECTOR INCREASES                                          1440.
 0099               DO 64 J3=1,5                                                        1441.
 0100               J=J3+J2                                                             1442.
 0101               INVST2(J)=INVST2(J)*(1+COMP)                                        1443.
 0102               IOVER2(J)=INVST2(J)-INEED2(J)                                       1444.
 0103            64 RGJ(J)=((INVST2(J)-INVST(J))/INVST(J))*100.0                        1445.
 0104               CCMP=0.0                                                            1446.
 0105               J2=5*(2-K1)                                                         1447.
              C**   FOR GIVING SECTOR, DECREASE FRACTION IS COMP                        1448.
 0106               DO 66 J3=1,5                                                        1449.
 0107               J=J3+J2                                                             1450.
 0108            66 COMP=COMP+INVST2(J)                                                 1451.
 0109               COMP=TRINS(K)/CCMP                                                  1452.
              C**   RESULTS OF SECTCR DECREASES                                         1453.
 0110               DO 68 J3=1,5                                                        1454.
 0111               J=J3+J2                                                             1455.
 0112               INVST2(J)=INVST2(J)*(1-COMP)                                        1456.
 0113               IOVER2(J)= INVST2(J)- INEED2(J)                                     1457.
 0114            68 RGJ(J)=((INVST2(J)-INVST(J))/INVST(J))*100                          1458.
              C**                                                                       1459.
              C**   INITIALIZE RG FOR INTRA SECTOR                                      1460.
 0115               DO 96 J=1,10                                                        1461.
 0116            96 DELRGJ(J)=0.0                                                       1462.
 0117            99 CONTINUE                                                            1463.
              C**                                                                       1464.
              C**    INTERSECTOR ROUTINE COMPLETE                                       1465.
              C**                                                                       1466.
              C**    BEGIN INTRASECTCR LOCP                                             1467.
              C**    EACH SECTOR DONE IN TURN (K=1,2)                                   1468.
              C**    RECALCULATE INUF(K) AND IDWN(K)                                    1469.
 0118                DO 999 K=1,2                                                       1470.
 0119                INUP2(K)=0.0                                                       1471.
 0120                IDWN2(K)=0.0                                                       1472.
 0121                J2=5*(2-K)                                                         1473.
 0122                DO 899 J3=1,5                                                      1474.
 0123                J=J2+J3                                                            1475.
 0124                IF (IOVER2(J).GE.0.0) GO TO 898                                    1476.
 0125                IDWN2(K)=IDWN2(K)-IOVER2(J)                                        1477.
 0126                GO TO 899                                                          1478.
 0127           898  INUP2(K)=INUP2(K)+IOVER2(J)                                        1479.
 0128           899  CONTINUE                                                           1480.
```

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FORTRAN IV G LEVEL  21                  STEP6              DATE = 73311        21/32/01                    PAGE 0005
              C**                                                                                    1481.
              C**    IF INUP2=0 NO ADJUSTMENT POSSIBLE                                               1482.
 0129                IF (INUP2(K).EQ.0.0) GO TO 599                                                  1483.
 0130                IF (INUP2(K).GE.ICWN2(K)) GC TO 1010                                            1484.
              C**    IF INUP .GE. IDWN ALL FUND DEMANDS (IOVER2 .LT.0) CAN BE MET                    1485.
 0131                GO TO 1500                                                                      1486.
              C**                                                                                    1487.
              C**    K2 IS AMT OF OVERAGE IN IOVER2 .GT.0 COMPONENTS THAT IS                         1488.
              C**             TAKEN FCR DEMANDS                                                      1489.
 0132          1010 K2=IDWN2(K)/INLF2(K)                                                             1490.
 0133                J=5*(2-K)                                                                       1491.
 0134                DO 1020 J3=1,5                                                                  1492.
 0135                J=J2+J3                                                                         1493.
              C**                                                                                    1494.
              C**    K3 IS ADJUSTMENT MULTIPLIER; =1 IF IOVER2.LT.0 AND # IS .LT.1                   1495.
              C**             IF IOVER2 IS .GE.0                                                     1496.
 0136                K3=K2                                                                           1497.
 0137                IF (IOVER2(J).GE.0.0) GO TO 1015                                                1498.
 0138                K3=1.0                                                                          1499.
              C**    CHANGE IN RATE CF GROWTH                                                        1500.
 0139          1015 DELRGJ(J)=(IOVER2(J)*K3*(-100.0))/INVST2(J)                                      1501.
 0140          1020 RGJ(J)=RGJ(J)+CELRGJ(J)                                                          1502.
 0141                GO TO 999                                                                       1503.
              C**                                                                                    1504.
              C**    LOOP IF IDWN(K).GT.INUP(K); ONLY PARTIAL MEETING OF DEMAND                      1505.
              C**             POSSIBLE                                                               1506.
              C**    K2 IS FRACTION CF DEMAND MET                                                    1507.
 0142          1500 K2=INUP2(K)/IDWK2(K)                                                             1508.
 0143                J2=5*(2-K)                                                                      1509.
 0144                DO 1510 J3=1,5                                                                  1510.
 0145                J=J2+J3                                                                         1511.
              C**                                                                                    1512.
              C**    K3 IS ADJUSTMENT MULTIPLIER; =1 IF IOVER2.GE.0;                                 1513.
              C**                             .LT.1 IF IOVER2 IS .LT. 0.0                            1514.
 0146                K3=K2                                                                           1515.
 0147                IF(IOVER2(J).LT.0.0) GO TO 1505                                                 1516.
 0148                K3=1.0                                                                          1517.
 0149          1505 DELRGJ(J)=(IOVER2(J)*K3*(-100.0))/INVST2(J)                                      1518.
 0150          1510 RGJ(J)=RGJ(J)+CELRGJ(J)                                                          1519.
              C**                                                                                    1520.
              C**    PRINT INTRASECTOR ACTION STATEMENT                                              1521.
 0151           999 CONTINUE                                                                         1522.
 0152                IF (NPRNT2.NE.1.0) GO TO 998                                                    1523.
 0153                WRITE(6,987)                                                                    1524.
 0154           987 FORMAT(T6,'NEW FUND ANNUAL GROWTH RATES',/,                                      1525.
                   1  T7,'(COMPONENT NO. — RATE)',/)                                                 1526.
 0155                WRITE(6,997) (RGJ(J),J=1,10)                                                    1527.
 0156           997 FORMAT(T6,' 1--',F5.2,2X,' 2--',F5.2,2X,' 3--',F5.2,2X,                          1528.
                   1' 4--',F5.2,2X,' 5--',F5.2,/,T6,' 6--',F5.2,2X,' 7--',                           1529.
                   2 F5.2,2X,' 8--',F5.2,2X,' 9--',F5.2,2X,'10--',F5.2)                              1530.
              C**                                                                                    1531.
              C**    INTRASECTOR ROUTINE DONE                                                        1532.
              C**                                                                                    1533.
              C**    SET STEP6 END PARAMETERS TO SEE IF THRESHCLDS CF MEASURES NEED                  1534.
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               C**        TO BE LOWERED                                                 1535.
 0157            998  PSUM1 = INUP2(1) + INUP2(2)                                       1536.
 0158                 PSUM2 = IDWN2(1) + IDWN2(2)                                       1537.
 0159                 RETURN                                                            1538.
 0160                 END                                                               1539.
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FORTRAN IV G LEVEL  21                STEP7              DATE = 73311        21/32/01              PAGE 0001

 0001                SUBROUTINE STEP7(PSUM1,PSUM2)                                      1540.
 0002                IMPLICIT REAL*4 (A-Z)                                              1541.
               C**   ADJUST LOL,QOL MEASURES TO RESPOND TO LACK OF INVESTMENT           1542.
               C**   FUNDS FOR PRIVATE AND/OR PUBLIC SECTOR IN FUTURE CYCLES            1543.
               C**                                                                      1544.
 0003                COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),PAINR(10),RESCR(20),      1545.
                   1       FSTCK(20),RSORT(10),RSOFT1(10),STDEP(20),PUCST(20),          1546.
                   2       MAINT(1C),OCST(10),ECST(20),REREC(20),ECSTR(20),FLAGR(20),   1547.
                   3     MECSTR(2C),INDX,INVST1(10),INVST(10),JCT(10),UTIL(10,20),      1548.
                   4       UTILT(20,10)                                                 1549.
 0004                COMMON/PRINT/NPRNT1,NPRNT2                                         1550.
 0005                INTEGER*4 INDX                                                     1551.
 0006                 INTEGER*4 R,J,K,NCYCLE                                            1552.
 0007                DIMENSICN DEGRAD(12),UPGRAD(12),MEASB2(15),MEASB1(15)              1553.
 0008                DATA DEGRAD/12*0.0/,  UPGRAD/12*0.0/                               1554.
 0009                COMMCN/CONST/BF,DT,DRA(65),NCYCLE,PG                               1555.
 0010                 CCMMCN/INTER7/OMEAS(15),UPPER                                     1556.
 0011                COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),DNJT1(15,10),COUNT1(15),1557.
                   1     MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                      1558.
 0012                DIMENSION MEAS2(15),INVOUT(10),INVST2(10),XUTIL(10,20)             1559.
 0013                REAL*4 INVOUT                                                      1560.
               C**                                                                      1561.
               C**   PRINT STEP7 HEACER                                                 1562.
 0014                IF (NPRNT2.NE.1.0) GC TO 104                                       1563.
 0015                WRITE(6,20)                                                        1564.
 0016           20   FORMAT(T6,'DEMAND THRESHOLC ADJUSTMENTS',/)                        1565.
               C**                                                                      1566.
 0017          104   IF(NCYCLE.GT.1) GO TO 102                                          1567.
 0018                DO 106 N=1,15                                                      1568.
 0019          106   OMEAS(N) = TMEAS(N)                                                1569.
               C**                                                                      1570.
               C**   INITIALIZE MEASURES FOR UPGRADE CHECK                              1571.
 0020          102    DO 10 N=1,15                                                      1572.
 0021                 MEASB2(N)=MEASB1(N)                                               1573.
 0022           10    MEASB1(N)= MEAS(N)                                                1574.
 0023                CTR=1.0                                                            1575.
               C**                                                                      1576.
               C**   MAJOR COMPUTATICN LCCP                                             1577.
 0024                CTR=1.0                                                            1578.
 0025                 DO 1000 N = 1,15                                                  1579.
 0026                 IF (N.GE.12) GC TC 1000                                           1580.
               C**   SETS POPULATION AFFECTED (SEE STEP3)                               1581.
 0027                 INDX=DN(N)                                                        1582.
               C**                                                                      1583.
               C**   CALCULATE NUMERATCR CF MEASURE                                     1584.
 0028                 SUM = 0.0                                                         1585.
 0029                 DO 40 J=1,10                                                      1586.
 0030                 MULT = CNJ(N,J) * JCT(J)                                          1587.
 0031           40    SUM = SUM + (MULT*0.1)                                            1588.
               C**   EXTRAPOLATE MEAS FOR NEXT CYCLE                                    1589.
 0032                 MEAS2(N) = SUM / (PCP(INDX)  * 1.1)                               1590.
               C**                                                                      1591.
               C**   IF MEAS O.K. GC TO UPGRADE (200)                                   1592.
 0033                 IF (MEAS2(N).CE.TMEAS(N)) GO TO 200                               1593.
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               C**   IF STEP6 ANSWERED FUNDS, DONT ADJUST TMEAS NEEDS                        1594.
 0034                  IF (PSUM1.GE.PSUM2) GO TO 1000                                          1595.
               C**   TMEAS SET TO MAX(0.05,MEAS2)                                              1596.
 0035                  TMEAS(N)=MEAS2(N)                                                       1597.
 0036                  IF (TMEAS(N).LT.0.05) TMEAS(N)=0.05                                     1598.
               C**                                                                             1599.
               C**   PRINT TMEAS DEGRADE STATEMENT                                             1600.
 0037                DEGRAD(N)=TMEAS(N)                                                        1601.
 0038                  GO TO 1000                                                              1602.
               C**                                                                             1603.
               C**   IF MEASB1 .GE. MEASB2 .GT. TMEAS, UPGRADE TMEAS TO MEASB2                 1604.
 0039             200  IF (MEASB2(N).LE.TMEAS(N)) GO TO 1000                                   1605.
 0040                  IF (MEASB1(N).LT.MEASB2(N)) GO TO 1000                                  1606.
 0041                  TMEAS(N)=MEASB2(N)                                                      1607.
               C**                                                                             1608.
               C**   PRINT TMEAS UPGRADE STATEMENT                                             1609.
 0042                UPGRAD(N)=TMEAS(N)                                                        1610.
               C     IF (NPRNT2.NE.1.0) GO TO 1000                                             1611.
               C     IF (CTR.NE.1.0) GO TO 51                                                  1612.
               C     WRITE(6,52)                                                               1613.
 0043            1000  CONTINUE                                                                1614.
 0044                IF (NPRNT2.NE.1.0) GO TO 314                                              1615.
 0045                DO 309 N=1,12                                                             1616.
 0046                IF (UPGRAD(N).NE.0.0.OR.DEGRAD(N).NE.0.0) GO TO 311                       1617.
 0047             309 CONTINUE                                                                 1618.
 0048                GO TO 314                                                                 1619.
 0049             311 WRITE(6,302)                                                             1620.
 0050             302 FORMAT(T6,'MEASURE',T20,'NEW VALUE',/,                                   1621.
                    1 T7,'NUMBER',T16,'UPGRADE  DEGRADE')                                      1622.
 0051                DO 303 N=1,12                                                             1623.
 0052                IF (UPGRAD(N).EQ.0.0.AND.DEGRAD(N).EQ.0.0) GO TO 303                      1624.
 0053                WRITE(6,304)  N,UPGRAD(N),DEGRAD(N)                                       1625.
 0054             303 CONTINUE                                                                 1626.
 0055             304 FORMAT(T6,I4,T16,2(F7.4,2X))                                             1627.
 0056             314 DO 319 N=1,12                                                            1628.
 0057                UPGRAD(N)=0.0                                                             1629.
 0058             319 DEGRAD(N)=0.0                                                            1630.
 0059                RETURN                                                                    1631.
 0060                 END                                                                      1632.
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FORTRAN IV G LEVEL  21                    STEP8              DATE = 73311          21/32/01                    PAGE 0001
 0001              SUBROUTINE STEF8
 0002              IMPLICIT REAL*4 (A-Z)                                                          1633.
            C**    CALCULATE GROWTH MODIFICATION FACTORS FOR POPULATION AND                       1634.
            C**    ADJUST RESOURCE STOCK PILES                                                    1635.
 0003              CCMMON/INTER/FMG,TOPTM1,AGEPT(65),AGEPT1(65)                                   1636.
                  1             ,TCPT,POPKT(4,6),AGRIT(4),FBR,FDT,PDTH(65)                        1637.
 0004               COMMON/TWO/MECST1(20),PILE(20),PILE1(20),CPILT1(20),MNRNR1(10)                1638.
                  1  ,PILET1(20),PNCAP(110,10),MJOT(10)                                           1639.
 0005              COMMON/CHAR/CJK1(6,10),CJK2(6,10),CJK3(6,10),CJK4(6,10),                       1640.
                  1             C1(6),C2(6),C3(6),C4(6),JO(10),ZIP                                1641.
 0006              COMMON/INTER2/RGJ(10),QOLT(10),QOLT1(10),MAINR(10),RESOR(20),                  1642.
                  1       ESTCK(20),RSORT(10),RSORT1(10),STDEF(20),RUCST(20),                     1643.
                  2       MAINT(1C),OCST(10),ECSTR(20),REREC(20),RECST(20),FLAGR(20),             1644.
                  3       MECSTR(20),INDX,INVST1(10),INVST(10),JOT(10),UTIL(10,20),               1645.
                  4       UTILT(2C,10)                                                            1646.
 0007              CCMMON/CONST/BR,CT,DRA(65),NCYCLE,MG                                           1647.
 0008              COMMCN/COST/RUCST1(20),RUCST2(20),KFACT(10)                                    1648.
 0009              INTEGER*4 INDX                                                                 1649.
 0010              INTEGER*4 JCTR,P, R,J,N,I,NCYCLE,PP,RR,KK5                                     1650.
 0011              COMMON/KDATA/K1(20),K2(20),K3(20),K4(20),K5(20),FLGDAT(18,4)                   1651.
 0012              COMMON/INTER3/CNJ(15,10),DN(15),TMEAS(15),DNJT1(15,10),COUNT1(15),             1652.
                  1     MDEL(10),RESIL(15),POP(8),VN(15),MEAS(15)                                 1653.
 0013              DIMENSION NPILE(20)                                                            1654.
 0014               COMMON/INTER6/XUTIL(17,20),XOCST(17),MARK(17),TIME(17),CTR,                   1655.
                  1  SUBIOP(400)                                                                  1656.
 0015              INTEGER*4 CTR                                                                  1657.
 0016              CCMMON/INTER4/SUBDAT(10,13),ORES(10,20),ROCST(10),SUBMAT(1000),                1658.
                  1   ICTR,SUBPIL(900),JCTR                                                       1659.
 0017              INTEGER*4 ICTR                                                                 1660.
 0018              CCMMON/INTER7/CMEAS(15),UPPER                                                  1661.
 0019              CCMMON/INTER8/RC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),                  1662.
                  1  SUMMAT(100,10),PUBDIV,PUBNUM,PRIDIV,PRINUM,TMEASO(15),SCAMSO                 1663.
 0020              CCMMCN/TWORK/W(RK(20)                                                          1664.
 0021              COMMON/CAPDAT/CAPLSE(10),CAPGRO(10),KEDIV(20)                                  1665.
 0022              DIMENSION DPILE(20),MNPOL2(10),XUTIL1(17,20)                                   1666.
            C**                                                                                   1667.
            C**    DEVELOP SCALAR QOL VALUE FCR POP MCDIFIER                                      1668.
            C**    IF FIRST CYCLE, FREEZE THRESHOLDS FOR SCALAR                                   1669.
 0023              IF (NCYCLE.GT.1) GO TO 1                                                       1670.
 0024              DO 2 N=1,15                                                                    1671.
 0025          2   TMEASO(N)=TMEAS(N)                                                             1672.
 0026          1   CONTINUE                                                                       1673.
 0027              SUM = 0.0                                                                      1674.
 0028              DO 10 N=1,15                                                                   1675.
            C**    VN IS WGT OF MEAS(N) IN VALLQL                                                 1676.
 0029              IF (N.EQ.12) GC TO 15                                                          1677.
 0030              PSUM = VN(N) * (MEAS(N)/TMEASO(N))                                             1678.
 0031         10    SUM  = PSUM  + SUM                                                            1679.
 0032         15   VALLQL  =  SUM                                                                 1680.
 0033              IF (NCYCLE.GT.1) GC TO 20                                                      1681.
 0034              SCAMSO=VALLQL                                                                  1682.
 0035         20   SUMMAT(NCYCLE,5)=VALLQL/SCAMSO                                                 1683.
            C**    MAXIMUM WORK UNITS IS PAID WORKER PCP                                          1684.
 0036              MWU  =  POP(5)                                                                 1685.
                                                                                                  1686.
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      C**
      C**   SET FACTORS
            KK=1.0
            KK2=KK/2.0
            KK4=KK/4.0
            KK8=KK/8.0
      C**
      C**   BIRTHRATE MODIFIER
            IF (VALLOL.GE.KK2) FBR=1.0
            IF (VALLOL.LT.KK4) FBR=0.0
            IF (VALLOL.GE.KK4.AND.VALLOL.LT.KK2) GC TO 30
            GO TO 40
         30 FBR = 1.0 - ((KK2-VALLOL)/(KK2-KK4))**2
      C**
      C**   DEATHRATE MODIFIER
         40 IF (VALLOL.GE.KK2) FDT=1.0
            IF (VALLOL.LT.KK8) FDT=(1.0 + KK4)
            IF (KK2.GT.VALLOL.AND.VALLOL.GE.KK8) GO TO 50
            GO TO 60
         50 FDT = 1.0 + (KK4*(((KK2-VALLOL)/(KK2-KK8))**2))
      C**
      C**   NET IMMIGRATICN MODIFIERS
         60 IF (VALLOL.GT.(3*KK4)) FMG=1.0
            IF (VALLOL.LT.KK2) FMG=0.0
            IF ((3*KK4).GT.VALLOL.AND.VALLOL.GE.KK2) GC TC 70
            GO TO 80
         70 FMG = 1.0 - (((3*KK4-VALLOL)/KK4)**2)
         80 FMG=FMG*(20.0 *ESTCK(18) - 18.0)
      C**
      C**   ADJUSTMENT OF WCRK FCRCE IF UNEMPLCYMENT IS LESS THAN 4%
            IF (ESTCK(18).LE.0.96) GO TO 76
            COMP=(ESTCK(18)-0.96)/0.96
            DO 72 J=1,10
            TEMP=CJK2(5,J)*CCMP
            IF ((CJK2(6,J)-TEMP).LE.0.0) TEMP=0.0
            CJK2(5,J)=CJK2(5,J)+TEMP
         72 CJK2(6,J)=CJK2(6,J)-TEMP
            DO 74 J=1,10
            TEMP=CJK3(5,J)*CCMP
            IF((CJK3(6,J)-TEMP).LT.0.0) TEMP=CJK3(6,J)
            CJK3(5,J)=CJK3(5,J)+TEMP
         74 CJK3(6,J)=CJK3(6,J)-TEMP
         76 CONTINUE
      C**
      C**   RESOURCE RESET
      C**   INITIALIZE I/C PROCESS MATRIX
            DO 330 R=1,20
            DO 330 J=1,17
        330 XUTIL1(J,R) = XUTIL(J,R)
      C**
      C**   EXPAND RESOURCE STOCK PILES
            JCTR=SUBPIL(1)
            DO 340 I=2,JCTR,3
            IF ((NCYCLE+1).NE.SUBPIL(I+1)) GO TO 340
```

```
0076                 R=SUBPIL(I)                                                             1741.
0077                  COMP=ESTCK(R)                                                          1742.
             C**     NEW LEVEL OF USE (ESTCK) AND PILE                                       1743.
0078                 ESTCK(R) = (ESTCK(R)*PILE(R))/(PILE(R)+SUBPIL(I+2))                     1744.
0079                 PILE(R)=PILE(R)+SUPPIL(I+2)                                             1745.
             C**     ADJUST COSTS IF THEY WERE IN ESCALATION RANGE (PILF .GE. 0.9)           1746.
0080                  IF (COMP.GT.0.9.AND.COMP.GT.ESTCK(P)) GO TO 335                        1747.
0081                  GO TO 340                                                              1748.
0082             335 COMP=0.9                                                                1749.
0083                 IF (COMP.LT.ESTCK(P)) COMP=ESTCK(R)                                     1750.
0084                  MECSTR(R)=0.00001*(K1(R)+(K2(P)*COMP**K3(R)))                          1751.
0085                  MECST1(P)=MECSTR(R)                                                    1752.
0086                  RUCST1(R)=MECST1(F)/(1+REFEC(R))                                       1753.
0087                 RUCST2(R)=RUCST1(R)                                                     1754.
0088            340  CONTINUE                                                                1755.
             C**                                                                             1756.
             C**     PHASE IN RESOURCE SUBSTITUTIONS                                         1757.
0089                 ICTR=SUBMAT(1)                                                          1758.
0090                 DO 341 I=2,ICTR,4                                                       1759.
0091                 IF ((NCYCLE+1).NE.SUBMAT(I)) GO TO 341                                  1760.
0092                 CCMP=SUBMAT(I+3)                                                        1761.
0093                 IDX=SUBMAT(I+2)                                                         1762.
0094                 R = SUBMAT(I+1)                                                         1763.
             C**     FOR (R,IDX) COMBINATIONS, UPDATE EACH I/C PROCESS                       1764.
0095                 DO 342 J=1,17                                                           1765.
0096                 IF (XUTIL1(J,R).EC.0.0) GO TO 342                                       1766.
             C**     LOWER RESOURCE BEING SUBSTITUTED FOR                                    1767.
0097                  TEMP=XUTIL1(J,R)                                                       1768.
0098                 XUTIL1(J,R)=XUTIL1(J,R)*(1-COMP)                                        1769.
             C**     LOOP TO INCREASE SUBSTITUTICN RESCURCES                                 1770.
0099                 DO 343 P=1,5                                                            1771.
0100                 PP=2*P+1                                                                1772.
0101                 PPP=SUBDAT(IDX,PP)                                                      1773.
0102                 IF(SUBDAT(IDX,PP+1).EQ.0.0) GO TO 343                                   1774.
0103                 XUTIL1(J,PPP)=XLTIL1(J,PPP)+(TEMP*CCMP*SUBDAT(IDX,PP+1))                1775.
0104            343  CONTINUE                                                                1776.
             C**                                                                             1777.
             C**     IF SUB COMPLETE (CCMP=1) ENTER INTO PERMANENT I.O PROCESS MATRIX        1778.
0105                 IF (CCMP.NE.1.C) GO TO 342                                              1779.
0106                 DO 344 RR=1,20                                                          1780.
0107            344  XUTIL(J,RR)=XUTIL1(J,RR)                                                1781.
0108            342  CONTINUE                                                                1782.
0109            341  CONTINUE                                                                1783.
             C**                                                                             1784.
             C**     LOWER STOCK PILE COUNTER FOR FUTURE EXPANSIONS                          1785.
0110                 DO 349 R=1,20                                                           1786.
0111             349 IF(WORK(R).GT.0.0) WORK(R)=WORK(P)-1.0                                  1787.
             C**                                                                             1788.
             C**     IN/OUT RESET                                                            1789.
0112                 I=0                                                                     1790.
             C**     CONSTRUCT ACTIVE I/O PROCESS MATRIX                                     1791.
0113                 DO 360 J=1,17                                                           1792.
0114                 IF (MBRK(J).EQ.0.0) GO TO 360                                           1793.
0115                 IF (MBRK(J).EQ.-1.0) GO TO 360                                          1794.
```

```
0116              I=I+1                                                          1795.
0117              DO 361 R=1,20                                                  1796.
0118          361 UTIL(I,R) = XUTIL1(J,R)                                        1797.
0119          360  CONTINUE                                                      1798.
             C**                                                                 1799.
             C**   MAKE TIME PHASEC I/O PROCESS ACJUSTMENTS                      1800.
0120               CTR=SUBICP(1)                                                 1801.
0121               DO 362 I=2,CTR,4                                              1802.
0122               IF ((NCYCLE+1).NE.SUBIOP(I+3)) GO TO 362                      1803.
0123               J=SUBIOP(I)                                                   1804.
0124               KK5=SUBIOP(I+1)                                               1805.
0125               COMP=SUBICP(I+2)                                              1806.
             C**   ACTUAL COMPUTATICN LOOP                                       1807.
0126                DO 363 R=1,20                                                1808.
0127           363  UTIL(J,R)=UTIL(J,R)*(1-CCMP)+XUTIL1(KK5,R)*COMP              1809.
             C**                                                                 1810.
             C**   IF TIME PHASE CCMPLETE, RESET ACTIVE I/O MARKER FILE          1811.
0128               IF(COMP.NE.1.0) GC TO 362                                     1812.
0129               MBRK(J)=0.0                                                   1813.
0130               MBRK(KK5)=1.0                                                 1814.
             C     WRITE(6,205) J,KK5,COMP                                       1815.
             C205  FORMAT(5X,'J,KK5,COMP',2X,2(I4,2X),2X,F15.4)                  1816.
0131          362  CONTINUE                                                      1817.
             C**   ALL TIME STEPS FOP MATRICES DONE                              1818.
             C**                                                                 1819.
             C**   RESET STOCK LEVELS, POP FCR NEXT CYCLE                        1820.
0132               DO 370 R=1,20                                                 1821.
0133               IF (R.EQ.18) GC TO 370                                        1822.
0134               IF (R.EQ.9) GO TO 371                                         1823.
0135               IF (R.EQ.14.OR.R.EQ.15.OR.R.EQ.16) GO TO 371                  1824.
0136               IF (R.EQ.17.OR.R.EG.19.OR.R.EQ.20) GO TO 371                  1825.
0137               STDEP(R)=ESTCK(R)                                             1826.
0138               GO TO 370                                                     1827.
0139          371  STDEP(R)=0.0                                                  1828.
0140          370  FLAGR(R)=0.0                                                  1829.
0141               TOPTM1=TCPT                                                   1831.
0142               DO 250 J=1,65                                                 1832.
0143          250 AGEPT1(J) = AGEPT(J)                                           1833.
             C**                                                                 1834.
             C**   STORE OUTPUT SUMMARY DATA                                     1835.
             C**   HERE IS THE PLACE FOR OUTPUT OPTIONS                          1836.
0144               I=NCYCLE                                                      1837.
0145               OUTMAT(I,1)=I                                                 1838.
0146               OUTMAT(I,2)=TOPT/203210.0                                     1839.
0147               DO 390 J=1,4                                                  1840.
0148          390  OUTMAT(I,2+J)=AGRIT(J)/203210.0                               1841.
0149               DO 391 J=1,10                                                 1842.
0150          391  OUTMAT(I,6+J)=JC(J)/1000.0                                    1843.
0151               DO 392 R=1,8                                                  1844.
0152          392  OUTMAT(I,16+R) = RESCR(R)/REDIV(R)                            1845.
0153               OUTMAT(I,25) = RESOR(9)/REDIV(9)                              1846.
0154               OUTMAT(I,26) = RESOR(11)/REDIV(11)                            1847.
0155               OUTMAT(I,27) = RESCR(12)/REDIV(12)                            1848.
0156               OUTMAT(I,28) = 0.0                                            1849.
```

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FORTRAN IV G LEVEL  21                STEP8              DATE = 73311         21/32/01                    PAGE 0005

 0157             OUTMAT(I,29) = RESOR(14)/REDIV(14)                                               1850.
 0158             OUTMAT(I,30) = RESCR(15)/REDIV(15)                                               1851.
 0159             OUTMAT(I,31) = RESOR(16)/REDIV(16)                                               1852.
 0160             OUTMAT(I,32) = (CAPUSE(1)+CAPUSE(2)+CAPUSE(3)+CAPUSE(4)+                         1853.
                 1      CAPUSE(5))/500.0                                                           1854.
 0161             OUTMAT(I,33) = (CAPUSE(6)+CAPUSE(7)+CAPUSE(8)+CAPUSE(9)+                         1855.
                 1      CAPUSE(10))/500.0                                                          1856.
 0162             OUTMAT(I,34) =1.0 - ESTCK(18)                                                    1857.
 0163             OUTMAT(I,35)=(RESOR(19)-1000.0)/(REDIV(19)-1000.0)                               1858.
 0164             OUTMAT(I,36)=(RESCR(20)-1000.0)/(REDIV(20)-1000.0)                               1859.
 0165             OUTMAT(I,37)=VALLOL                                                              1860.
 0166             RETURN                                                                           1861.
 0167             END                                                                              1862.
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FORTRAN IV G LEVEL  21                PLOT                DATE = 73311         21/32/01              PAGF 0001

 0001               SUBRCUTINE PLCT(NC,A,M,N,NL,NS,ANG)                                      1863.
              C**   THIS IS THE PLCT PROGRAM                                                 1864.
              C      SUBROUTINE PLCT                                                         1865.
              C     PURPOSE                                                                  1866.
              C        PLOT SEVERAL CROSS-VARIABLES VERSUS A BASE VARIABLF                   1867.
              C     USAGE                                                                    1868.
              C        CALL PLOT (NC,A,N,M,NL,NS,ANG)                                        1869.
              C     DESCRIPTION OF PARAMETERS                                                1870.
              C        NO - CHART NUMBER (3 DIGITS MAXIMUM)                                  1871.
              C        A - MATRIX CF DATA TO BF PLCTTED. FIRST COLUMN REPRESENTS             1872.
              C          BASE VARIABLE AND SUCCESSIVE COLUMNS ARE THE CROSS-                 1873.
              C          VARIABLES (MAXIMUM IS 9).                                           1874.
              C        N - NUMBER OF ROWS IN MATRIX A                                        1875.
              C        M - NUMBER CF COLUMNS IN MATRIX A -EQUAL TO THE TOTAL                 1876.
              C          NUMBER OF VARIABLES). MAXIMUM IS 10.                                1877.
              C        NL - NUMBER OF LINES IN THE PLOT. IF 0 IS SPECIFIEC, 50               1878.
              C          LINES ARE LSED.                                                     1879.
              C        NS - CODE FCR SCRTING THE BASE VARIABLE DATA IN ASCENDING             1880.
              C          ORDER                                                               1881.
              C             0 SCRTING IS NOT NECESSARY (ALREACY IN ASCENDING                 1882.
              C               ORDER).                                                        1883.
              C             1 SORTING IS NECESSARY.                                          1884.
              C     REMARKS                                                                  1885.
              C        NONE                                                                  1886.
              C     SUBROUTINES ANC FUNCTION SUBPROGRAMS REQUIPED                            1887.
              C        NCNE                                                                  1888.
 0002               DIMENSION NO(7),OUT(101,52),XPR(11),ANG(9),A(1000)                       1889.
 0003               DATA BLANK/'    '/                                                       1890.
              C                                                                              1891.
 0004             1 FORMAT(1H1,'                     ',30X,7A4,//)                           1892.
 0005             2 FORMAT(1H ,4X,F7.1,5X,101A1)                                             1893.
 0006             3 FORMAT(1H )                                                              1894.
 0007             4 FORMAT(10H 123456789)                                                    1895.
 0008             5 FORMAT(10A1)                                                             1896.
 0009             7 FORMAT(1H ,16X,101H'         '         '         '         '             1897.
                 1 YEARS         '         '         '         '         ')                  1898.
 0010             8 FORMAT(1H0,9X,11F10.1)                                                   1899.
 0011             9 FORMAT(1H,16X,101A1)                                                     1900.
 0012               NLL=NL                                                                   1901.
              C        TEST NLL                                                              1902.
              C                                                                              1903.
 0013            16 IF(NLL) 20, 18, 20                                                       1904.
 0014            18 NLL=50                                                                   1905.
              C        PRINT TITLE                                                           1906.
              C                                                                              1907.
 0015            20 WRITE(6,1)NO                                                             1908.
              C                                                                              1909.
              C     SET HORIZONTAL SPACING                                                   1910.
 0016               NP=1                                                                     1911.
 0017               IF(N.LT.51) NP=2                                                         1912.
 0018               IF(N.LT.34) NP=3                                                         1913.
 0019               IF(N.LT.26) NP=4                                                         1914.
              C                                                                              1915.
              C     CLEAR MATRIX                                                             1916.
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```
0020              DO 10 J = 1,101                                                        1917.
0021              DO 10 I = 1,52                                                         1918.
0022           10 OUT(J,I) = BLANK                                                       1919.
            C                                                                            1920.
            C     SET STORAGE COLNTERS                                                   1921.
0023              I = 1                                                                  1922.
0024              II = 1                                                                 1923.
0025              MY = N-1                                                               1924.
            C                                                                            1925.
            C     DEVELOP ALPHA MATRIX                                                   1926.
0026           22 DO 30 J = 1,MY                                                         1927.
0027              JR=1                                                                   1928.
0028              LL = I + J*N                                                           1929.
0029              IF(A(LL).LE.0.0) A(LL)=0.0                                             1930.
0030              JP =(A(LL)/0.08) + 1.0                                                 1931.
0031              IF (JP.GT.51) JR = 52                                                  1932.
0032              IF (JR.EQ.52) GO TO 30                                                 1933.
0033              JR = 52 -JP                                                            1934.
0034           30 OUT(II,JR) = ANG(J)                                                    1935.
0035              I = I + 1                                                              1936.
0036              II = II + NP                                                           1937.
0037              IF (I.LE.N) GO TO 22                                                   1938.
            C                                                                            1939.
            C     SET COUNTERS FCR CRDINATE PRINT                                        1940.
0038              L = 0                                                                  1941.
0039              YPR = 4.4                                                              1942.
0040              WRITE(6,7)                                                             1943.
0041              DO 40 J = 1,51                                                         1944.
0042              IF (L) 50,50,60                                                        1945.
0043           50 YPR = YPR - 0.4                                                        1946.
0044              L =5                                                                   1947.
0045              WRITE(6,2) YPR,(OUT(I,J),I = 1,101)                                    1948.
0046              GO TO 40                                                               1949.
0047           60 WRITE(6,9)(OUT(I,J),I = 1,101)                                         1950.
0048           40 L = L - 1                                                              1951.
            C                                                                            1952.
            C     PRINT ABSCISSA                                                         1953.
0049              XPR(1) = 1.0                                                           1954.
0050              DO 70 I = 1,10                                                         1955.
0051           70 XPR(I+1) = XPR(I) + (10.0/NP)                                          1956.
0052              WRITE (6,7)                                                            1957.
0053              WRITE (6,8) (XPR(I),I =1,11)                                           1958.
0054              WRITE (6,9) (OUT(I,52),I = 1,101)                                      1959.
0055              RETURN                                                                 1960.
0056              END                                                                    1961.
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FORTRAN IV G LEVEL  21                  OUTPUT               DATE = 73311        21/32/01              PAGE 0001

 0001              SUBROUTINE OUTPUT                                                        1962.
             C**                                                                            1963.
             C**   SETS UP THE OUTPUT                                                       1964.
 0002              COMMON/DPLOT/PLTMAT(10,100),PPLOT                                        1965.
 0003              COMMON/INTER8/FC,CPILE(20),CAPVL(10),OUTMAT(100,40),MBRK(17),            1966.
                  1  SUMMAT(100,10),PUBDIV,PUBNUM,PRICIV,PRINUM,THEASO(15),SCAMSO           1967.
 0004              COMMON/CCNST/BR,DT,DRA(65),NCYCLE,MG                                     1968.
 0005              REAL*4 MBRK,MG                                                           1969.
             C**                                                                            1970.
 0006              DIMENSION NO(7),N1(7),N2(7),N3(7),N4(7),N5(7),N6(7),N7(7)                1971.
 0007              DATA NO/'STAT','E OF',' THE',' SYS','TEM ','    ','    '/               1972.
 0008              DATA N1/'POPU','LATI','ON  ','    ','    ','    ','    '/               1973.
 0009              DATA N2/'PUBL','IC S','ECTC','R   ','    ','    ','    '/               1974.
 0010              DATA N3/'PRIV','ATE ','SECT','OR  ','    ','    ','    '/               1975.
 0011              DATA N4/'NATU','RAL ','RESO','URCE','S   ','    ','    '/               1976.
 0012              DATA N5/'ENER','GY  ','& AG','RICU','LTUR','E(2)','    '/               1977.
 0013              DATA N6/'EMPL','OYME','NT, ','QOL ','    ','    ','    '/               1978.
 0014              DATA N7/'LAND','(3),',' AIR',' AND',' WAT','ER  ','    '/               1979.
 0015              DIMEKSION A(1000)                                                        1980.
 0016              DIMENSION ANG1(S),ANG2(9),ANG3(9),ANG4(9),ANG5(9),ANG6(9),ANG7(9)        1981.
 0017              DIMENSION ANGO(9)                                                        1982.
 0018              DATA ANGO/'P   ','G   ','I   ','Q   ','N   ','E   ','F   ',            1983.
                  1          'W   ','M   '/                                                 1984.
 0019              DATA ANG1/'P   ','1   ','2   ','3   ','4   ','    ','    ',            1985.
                  1          '    ','    '/                                                 1986.
 0020              DATA ANG2/'E   ','T   ','H   ','D   ','W   ','    ','    ',            1987.
                  2          '    ','    '/                                                 1988.
 0021              DATA ANG3/'H   ','L   ','C   ','F   ','R   ','    ','    ',            1989.
                  3          '    ','    '/                                                 1990.
 0022              DATA ANG4/'I   ','C   ','L   ','M   ','S   ','T   ','    ',            1991.
                  4          '    ','    '/                                                 1992.
 0023              DATA ANG5/'C   ','O   ','E   ','T   ','F   ','    ','    ',            1993.
                  5          '    ','    '/                                                 1994.
 0024              DATA ANG6/'U   ','Q   ','    ','    ','    ','    ','    ',            1995.
                  6          '    ','    '/                                                 1996.
 0025              DATA ANG7/'U   ','S   ','F   ','A   ','W   ','    ','    ',            1997.
                  7          '    ','    '/                                                 1998.
             C**                                                                            1999.
 0026              DO 10 I=1,1000                                                           2000.
 0027           10 A(I)=0.0                                                                 2001.
             C**                                                                            2002.
             C**                                                                            2003.
             C**   PRINT SUMMARY CATA                                                       2004.
 0028              WRITE(6,1001)                                                            2005.
 0029         1001 FORMAT(1H1,46X,'SUMMARY TABLE - STATE OF THE SYSTEM',/,                  2006.
                  1   51X,'(SCALEC TO ORIGINAL VALUE)',//,30X,'PUBLIC',5X,'PRIVATE',        2007.
                  2   5X,'QLALITY',3X,'NATURAL',7X,'ENERGY',3X,'FARM AND',5X,               2008.
                  3   'EMPLOYED',4X,'TREATED',/,9X,'YEAR',1X,'POPULATION',7X,'FUNDS',2009.
                  4  6X,'FUNDS',7X,'LEVEL',3X,'ORE USAGE',7X,'USAGE',2X,'LAND USAGE',2010.
                  5  5X,'WORKERS',3X,'ECO-MEDIA',/,19X,'(P)',9X,'(G)',9X,'(I)',         2011.
                  6  9X,'(Q)',8X,'(N)',9X,'(E)',9X,'(F)',9X,'(U)',9X,'(M)',/)           2012.
 0030              DO 1500 I=1,NCYCLE                                                       2013.
 0031         1500 WRITE(6,1003) (SLMMAT(I,J),J=1,10)                                       2014.
 0032         1003 FORMAT(9X,F3.0,4X,F7.4,5X,F7.4,4X,F7.4,6(5X,F7.4))                       2015.
 0033            KK=1
 0034            DO 1510 J=1,10
 0035            DO 1510 I=1,NCYCLE
 0036            A(KK)=SUMMAT(I,J)
 0037       1510 KK=KK+1
 0038            M1=10
 0039            NL1=50
 0040            NS1=1
 0041            CALL PLOT(NO,A,M1,NCYCLE,NL1,NS1,ANG0)
           C**
 0042            DO  20 I=1,NCYCLE
 0043            DO 20 J=1,6
 0044         20 PLTMAT(J,I)=OUTMAT(I,J)
 0045            WRITE(6,26)
 0046         26 FORMAT(1H1,T37,'TABLE NUMBER ONE - POPULATION',/,
                1  T39,'(SCALED TO ORIGINAL VALUE)',//,T23,'TOTAL',T40,'UNDER',
                2  T57,'18-24',T73,'25-64',T88,'OVER',/,T10,'YEAR',
                3  T20,'POPULATICN',T38,'18 YEARS',T57,'YEARS',T73,'YEARS',
                4  T86,'64 YEARS',/,T25,'(P)',T41,'(1)',T57,'(2)',T73,'(3)',
                5  T89,'(4)',/)
 0047            DO 25 I=1,NCYCLE
 0048         25 WRITE(6,27) (PLTMAT(J,I),J=1,6)
 0049         27 FORMAT(9X,F3.0,5(9X,F7.4))
 0050            IF (PPLOT.EQ.0.0) GO TO 2000
 0051            KK=1
 0052            DO 28 J=1,6
 0053            DO 28 I=1,NCYCLE
 0054            A(KK)  = OUTMAT(I,J)
 0055            KK=KK+1
 0056         28 CONTINUE
 0057             M1=6
 0058             NS1=1
 0059            CALL PLOT (N1,A,M1,NCYCLE,NL1,NS1,ANG1)
           C**
 0060       2000 DO 30 I=1,NCYCLE
 0061            DO 30 J=7,11
 0062            K=J-5
 0063         30 PLTMAT(K,I)=OUTMAT(I,J)
 0064            WRITE(6,35)
 0065         35 FORMAT(1H1,T31,'TABLE NUMBER TWO - PUBLIC SECTOR OUTPUT UNITS',/,
                1  T39,'(SCALED TO ORIGINAL VALUE)',//,T70,'DEFENSE',/,
                2 T10,'YEAR',T21,'EDUCATION',T32,'TRANSPORTATION',T56,'HEALTH',T69,
                3  'AND OTHER',T87,'WELFARE',/,T25,'(E)',T42,'(T)',T57,'(H)',
                4  T73,'(D)',T89,'(W)',/)
 0066            DO 36 I=1,NCYCLE
 0067         36 WRITE(6,37) (PLTMAT(K,I),K=1,6)
 0068         37 FORMAT(9X,F3.0,5(9X,F7.4))
 0069            IF (PPLOT.EQ.0.0) GO TO 4000
           C**
 0070            KK=1+NCYCLE
 0071             M1=6
 0072             NS1=1
 0073            DO 38 J=7,11
 0074            DO 38 I=1,NCYCLE
 0075            A(KK)  = OUTMAT(I,J)                                          2070.
 0076            KK=KK+1                                                       2071.
 0077         38 CONTINUE                                                      2072.
 0078            CALL PLOT (N2,A,M1,NCYCLE,NL1,NS1,ANG2)                       2073.
           C**                                                                 2074.
 0079       4000 DO 40 I=1,NCYCLE                                              2075.
 0080            DO 40 J=12,16                                                 2076.
 0081            K=J-10                                                        2077.
 0082      40    PLTMAT(K,I)=OUTPAT(I,J)                                       2078.
 0083            WRITE(6,45)                                                   2079.
 0084      45    FORMAT(1H1,T29,'TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS',2080.
               1  /,T38,'(SCALEC TO ORIGINAL VALUE)',//,T19,'HFAVY POLL.',T35,  2081.
               2  'LIGHT POLL.',T83,'HOUSEHOLD &',/,T10,'YEAR',T19,'MANUFACTURE', 2082.
               3  T35,'MANUFACTURE',T52,'CCMMERCIAL',T67,'AGRICULTURE',T84,      2083.
               4  'RECREATION',/,T25,'(H)',T41,'(L)',T57,'(C)',T73,'(F)',T89,   2084.
               5  '(R)',/)                                                     2085.
 0085            DO 46 I=1,NCYCLE                                              2086.
 0086      46    WRITE(6,47) (PLTMAT(K,I),K=1,6)                               2087.
 0087      47    FORMAT(9X,F3.0,5(5X,F7.4))                                    2088.
 0088            IF (PPLOT.EQ.0.0) GO TO 5000                                  2089.
           C**                                                                 2090.
 0089            KK=1+NCYCLE                                                   2091.
 0090             M1=6                                                         2092.
 0091             NS1=1                                                        2093.
 0092            DO 48 J=12,16                                                 2094.
 0093            DO 48 I=1,NCYCLE                                              2095.
 0094            A(KK)  = OUTMAT(I,J)                                          2096.
 0095            KK=KK+1                                                       2097.
 0096         48 CONTINUE                                                      2098.
 0097            CALL PLOT (N3,A,M1,NCYCLE,NL1,NS1,ANG3)                       2099.
           C**                                                                 2100.
 0098       5000 DO 50 I=1,NCYCLE                                              2101.
 0099            DO 50 J=17,22                                                 2102.
 0100            K=J-15                                                        2103.
 0101      50    PLTMAT(K,I) = CLTPAT(I,J)                                     2104.
 0102            WRITE (6,55)                                                  2105.
 0103      55    FORMAT(1H1,T39,'TABLE NUMBER FOUR - NATURAL RESOURCES USAGE',/, 2106.
               1  T47,'(SCALED TO ORIGINAL VALUE)',//,T56,'LEAC',T105,'TRACE',  2107.
               2  /,T10,'YEAR',T26,'IRON',T40,'COPPER',T54,'AND ZINC',T71,      2108.
               3  'MERCURY',T88,'SILVER',T106,'ORES',/,T25,'(I)',T41,'(C)',    2109.
               4  T57,'(L)',T73,'(M)',T89,'(S)',T105,'(T)',/)                  2110.
 0104            DO 56 I=1,NCYCLE                                              2111.
 0105      56    WRITE(6,57) (PLTMAT(K,I),K=1,7)                               2112.
 0106      57    FORMAT(9X,F3.0,6(9X,F7.4))                                    2113.
 0107            IF (PPLOT.EQ.0.0) GO TO 6000                                  2114.
           C**                                                                 2115.
 0108            KK=1+NCYCLE                                                   2116.
 0109             M1=7                                                         2117.
 0110             NS1=1                                                        2118.
 0111            DO 58 J=17,22                                                 2119.
 0112            DO 58 I=1,NCYCLE                                              2120.
 0113            A(KK)  = OUTMAT(I,J)                                          2121.
 0114            KK=KK+1                                                       2122.
 0115         58 CONTINUF                                                      2123.
```

```
FORTRAN IV G LEVEL  21              OUTPUT              DATE = 73311          21/32/01             PAGE 0004
  0116                   CALL PLOT (N4,A,M1,NCYCLE,NL1,NS1,ANG4)                                         2124.
                  C**                                                                                    2125.
  0117             6000  DO 60 I=1,NCYCLE                                                                2126.
  0118                   DO 60 J=23,27                                                                   2127.
  0119                   K=J-21                                                                          2128.
  0120                   PLTMAT(K,I)=OUTPAT(I,J)                                                         2129.
  0121               60  CONTINUE                                                                        2130.
  0122                   WRITE(6,65)                                                                     2131.
  0123               65  FORMAT(1H1,T29,'TABLE NUMBER FIVE - ENERGY & AGRICULTURAL USAGE',/2132.
                        1  ,T39,'(SCALED TO ORIGINAL VALUE)',//,                                         2133.
                        2  T10,'YEAR',T26,'COAL',T43,'OIL',T51,'ELECTRICITY',T72,'TIMBER', 2134.
                        3 T90,'FOOD',/,T25,'(C)',T41,'(O)',T57,'(E)',T73,'(T)',T89, (F)',/)2135.
  0124                   DO 66 I=1,NCYCLE                                                                2136.
  0125               66  WRITE (6,67) (FLTMAT(K,I),K=1,6)                                                2137.
  0126               67  FORMAT(9X,F3.0,5(8X,F8.4))                                                      2138.
  0127                   IF (PPLOT.EQ.0.0) GO TO 7000                                                    2139.
                  C**                                                                                    2140.
  0128                   KK=1+NCYCLE                                                                     2141.
  0129                   DO 16 II=KK,10C0                                                                2142.
  0130                16 A(II)=0.0                                                                       2143.
  0131                    M1=6                                                                           2144.
  0132                    NS1=1                                                                          2145.
  0133                   DO 68 J=23,27                                                                   2146.
  0134                   DO 68 I=1,NCYCLE                                                                2147.
  0135                   A(KK) = OUTMAT(I,J)                                                             2148.
  0136                   IF(A(KK).GT.7.0) A(KK)=7.0                                                      2149.
  0137                   KK=KK+1                                                                         2150.
  0138                68 CONTINUE                                                                        2151.
  0139                   CALL PLOT (N5,A,M1,NCYCLE,NL1,NS1,ANG5)                                         2152.
                  C**                                                                                    2153.
  0140             7000 DO 70 I=1,NCYCLE                                                                 2154.
  0141                   PLTMAT(2,I) = CUTMAT(I,34)                                                      2155.
  0142               70  PLTMAT(3,I) = OUTMAT(I,37)                                                      2156.
  0143                   WRITE(6,75)                                                                     2157.
  0144               75  FORMAT(1HI,T24,'TABLE NUMBER SIX',/,                                            2158.
                        1 T19,'UNEMPLOYMENT AND QOL VALUES',//,                                          2159.
                        2  T10,'YEAR',T23,'UNEMPLOYMENT',T49,'QUALITY',/,                                2160.
                        3  T30,'(U)',T51,'(Q)',/)                                                        2161.
  0145                   DO 76 I=1,NCYCLE                                                                2162.
  0146               76  WRITE(6,77) (PLTMAT(K,I),K=1,3)                                                 2163.
  0147               77  FORMAT(9X,F3.0,2(14X,F7.4))                                                     2164.
  0148                   IF (PPLOT.EQ.0.0) GO TO 8000                                                    2165.
                  C**                                                                                    2166.
  0149                   KK=1+NCYCLE                                                                     2167.
  0150                   DO 17 II=KK,1000                                                                2168.
  0151                17 A(II)=0.0                                                                       2169.
  0152                    M1=3                                                                           2170.
  0153                    NS1=1                                                                          2171.
  0154                   DO 71 I=1,NCYCLE                                                                2172.
  0155                   A(KK)=OUTMAT(I,34)                                                              2173.
  0156                   KK=KK+1                                                                         2174.
  0157               71  CONTINUE                                                                        2175.
  0158                   DO 72 I=1,NCYCLE                                                                2176.
  0159                   A(KK)=OUTMAT(I,37)                                                              2177.
```

```
FORTRAN IV G LEVEL  21              OUTPUT           DATE = 73311        21/32/01              PAGE 0005

 0160              KK=KK+1                                                           2178.
 0161        72    CONTINUE                                                          2179.
 0162              CALL PLOT (N6,A,M1,NCYCLE,NL1,NS1,ANG6)                           2180.
          C**                                                                        2181.
 0163      8000    DO 80 I=1,NCYCLE                                                  2182.
 0164              DO 81 J=29,31                                                     2183.
 0165              K=J-27                                                            2184.
 0166       81     PLTMAT(K,I) = CUTMAT(I,J)                                         2185.
 0167              PLTMAT(5,I) = CLTMAT(I,35)                                        2186.
 0168       80     PLTMAT(6,I) = CUTMAT(I,36)                                        2187.
 0169              WRITE (6,85)                                                      2188.
 0170       85     FORMAT(1H1,T29,'TABLE NUMBER SEVEN - LAND, AIR AND WATER',        2189.
                  1  ' USAGE',/,T39,'(SCALED TO ORIGINAL VALUE)',//,                 2190.
                  2  T10,'YEAR',T25,'URBAN',T38,'SUBURBAN',T56,'ARABLE',T72,         2191.
                  3  'TREATED UNITS OF MEDIA',/,T25,'(U)',T41,'(S)',                 2192.
                  3  T57,'(F)',T73,'(A)',T89,'(W)',/)                                2193.
 0171              DO 86 I=1,NCYCLE                                                  2194.
 0172       86     WRITE(6,87) (PLTMAT(K,I),K=1,6)                                   2195.
 0173       87     FORMAT(9X,F3.0,5(9X,F7.4))                                        2196.
 0174              IF (PPLOT.EQ.0.0) GO TO 9999                                      2197.
          C**                                                                        2198.
 0175              KK=1+NCYCLE                                                       2199.
 0176               M1=6                                                             2200.
 0177               NS1=1                                                            2201.
 0178              DO 88 J=2,6                                                       2202.
 0179              DO 88 I=1,NCYCLE                                                  2203.
          C        IF (J.EQ.32) J=35                                                 2204.
          C        IF (J.EQ.33) J=36                                                 2205.
 0180              A(KK) = PLTMAT(J,I)                                               2206.
 0181              KK=KK+1                                                           2207.
 0182         88   CONTINUE                                                          2208.
 0183              CALL PLOT (N7,A,M1,NCYCLE,NL1,NS1,ANG7)                           2209.
          C**                                                                        2210.
 0184       9999   RETURN                                                            2211.
 0185              END                                                               2212.
```

APPENDIX 4

USERS GUIDE FOR OPERATING SOS MODEL USING WYLBUR ON THE OSI COMPUTER

Sign-On Procedure

The procedure described below is for operating the SOSMDL Program, using WYLBUR with an Acoustic Coupler.

1. For a 10-15 cps terminal, check to see that the DUPLEX switch, located on the back of the coupler, is in the FULL position and that the ACST-TEL.TERM. switch, also on the back of the coupler, is set to ACST. In the case of the 30 cps terminal the duplex switch located on the front of the coupler, should be in HALF position.
2. Turn the terminal on.
3. Dial the number of the computer (OSI 652-9028 for 30 cps, and 654-1370 for 10-15 cps) on your telephone. When the computer answers with its high-pitched tone, place the hand set in the cradle of the coupler, with the cord coming out the front.
4. Turn on the coupler. The light underneath the ON-OFF switch will come on and remain on as long as the terminal is connected to the computer.
5. Press the RETURN key on the terminal. If the terminal has a Correspondence Keyboard, then type COR followed by a carriage return. If it is a 30 cps terminal, then the system will ask the user to supply the model number.

The user should type in the number 33, followed by a carriage return (CR) as follows:

```
MODEL? 33 (CR)
```

The system will respond by first typing the name of the installation followed by the telephone line number, date and time.

```
OSI/WYLBUR XX MM/DD/YY HH:MM:SS P.M.
```

This signifies that the terminal is ready to receive information.

The system will follow this with another line giving the message of the day which includes any special information of which the user should be aware.

In these examples, for the sake of clarity, the system response is always in upper case letters whereas what the user should type is in lower case letters.

Now the system will type the prompt, "INITIALS?". The user should answer by typing his registered initials and a carriage return (CR).

```
INITIALS? rpm (CR)
```

Next the user is asked to identify himself by giving his account number.

```
ACCOUNT? a053 (CR)
```

Then the user is asked to supply a keyword

```
KEYWORD? rpm (CR)
```

Provided that the correct response is made, the user is asked to supply the number of the terminal which he is using.

```
TERMINAL? t70 (CR)
COMMAND?
```

The system has now completed the sign-on procedure and the terminal is now ready to accept WYLBUR commands. The system response "COMMAND?" can be answered as follows:

```
COMMAND? set terse (CR)
```

The SET TERSE command causes the WYLBUR command prompt to be shortened from "COMMAND?" to "?."

The user may now type in the SET VOL command. This command sets for the user a default volume. Since the data set SOSMDL is stored on the TSO002 volume, the user may now type the following command in response to "?."

```
?  set vol = tso002 (CR)
```

In order to bring back a copy of the data set SOSMDL, the user should issue a USE command

```
? use SOSMDL (CR)
```

After receiving this information, WYLBUR will locate the data set and make a copy of it available for use as the working data set.

USE OF THE PRINT OPTIONS PROVIDED IN SOSMDL

The print switches provided are:

NAME OF SWITCH	DEFAULT VALUE	DESCRIPTION	APPROXIMATE LINES OF OUTPUT*
NPRNT1	1.0	Print-out for STEP1, STEP2 and STEP3 of SOSMDL	1860
NPRNT2	1.0	Print-out for STEP4, STEP5, STEP6, STEP7 and STEP8 of SOSMDL	900
PPLOT	1.0	Print-out for all the graphs of SOSMDL	480

*Assumes a 25 year simulation output history

If no print-out from STEP1, STEP2 and STEP3 is desired then the user must use the following procedure:

```
? mod 65  (CR)
 65.     DATA NPRNT1/1.0/,   NPRNT2/1.o/
ALTERS?                r2 (CR)
 65.     DATA NPRNT1/2.0/,   NPRNT2/1.0/
ALTERS? (CR)
?
```

If no print out from STEP3, STEP4, STEP5, STEP6, STEP7 and STEP8 is desired then the user must use the following procedure:

```
? mod 65  (CR)
65.      DATA NPRNT1/1.0/,   NPRNT2/1.0/
ALTERS?
                                      r2 (CR)
65.      DATA NPRNT1/1.0/,   NPRNT2/2.0/
ALTERS? (CR)
?
```

If no graphs of the SOSMDL are desired then the user must use the following procedure:

```
? mod 244 (CR)
244.     DATA PLTMAT/250*0.0/,   PPLOT/1.0/
ALTERS?
                                      r0 (CR)
244.     DATA PLTMAT/250*0.0/,   PPLOT/0.0/
ALTERS? (CR)
?
```

If data modifications are to be made then use APPENDIX 3 for WYLBUR line number reference. As an example, if rate of growth data needs to be changed then use the following procedure:

```
? mod 105(CR)
105.     DATA RGJ/8.2,3.4,9.9,5.0,8.8,4.7,4.6,2.2,0.3,3.8/,
ALTERS?          r4.6 (CR)
105.      DATA RGJ/8.2,4.6,9.9,5.0,8.8,4.7,4.6,2.2,0.3,3.8/,
ALTERS? (CR)
?
```

After all required modifications have been made, the user must submit the job through WYLBUR to be processed by the computer

```
? run (CR)
266 IS YOUR JOB NUMBER
?
```

The RUN command directs WYLBUR to put the user's working data set into the input stream. The output of this run will be printed at the OSI Central Computer Facility, Bethesda.

Users who have available a high speed remote station can have their output diverted to it. They indicate in the command the remote station number they want their output on.

```
? run remote = xx (CR)
```

After a job has been submitted through WYLBUR the user may wish to find out what (if any) processing has been done to it. The LOCATE command can be used to do this

```
? loc 266 (CR)
```

WYLBUR will respond with one of several messages indicating the state the job is in:

1. AWAITING EXECUTION - the job is waiting to be run.
2. IN HOLD STATUS - the operator must take some action before the job is run.
3. BEING EXECUTED - the job is running.
4. AWAITING PRINT - the job had run and the output is awaiting to be printed.
5. BEING PRINTED - the output is being printed
6. NOT LOCATABLE - the job has been completed and has left the system.

Sign-Off Procedure

To end a WYLBUR session the LOGOFF command is used. The CLEAR option should be typed to indicate if it is O.K. to clear the working data set. WYLBUR will reply with various statistics on the session and disconnect the telephone line.

```
? LOGOFF CLR (CR)
EDITING TIME = 9.80 SECONDS
WYLBUR EXCPS = 1287
MILTEN EXCPS = 922
RESOURCE TIME = 80.19 SECONDS
ELAPSED TIME = 00:04:32
END OF SESSION.
```

APPENDIX 5

PROCEDURE FOR CODE MODIFICATIONS AND EDITING A DATA SET USING WYLBUR

I. To list lines the user may use the LIST command. e.g.

```
COMMAND?  list 7/9 (CR)
```

This will list WYLBUR line numbers 7 through 9

```
COMMAND? list 7,9 (CR)
```

This will list WYLBUR line number 7 and 9

```
COMMAND?  list 7 (CR)
```

This will list WYLBUR line number 7

II. The user may delete (erase) a series of lines by giving the DELETE command and the numbers of the first and last lines of the range he wants erased.

```
COMMAND?  del 7/9 (CR)
```

A single line can be erased as follows:

```
COMMAND?  del 7 (CR)
```

III. The INSERT command is used to insert one or more lines.

```
COMMAND?  ins  12.02 (CR)
12.02?  (User supplied text) (CR)
COMMAND?
```

```
COMMAND?  ins  12.02, 12.03 (CR)
12.02?  (User supplied text) (CR)
12.03?  (User supplied text) (CR)
COMMAND?
```

IV. The MODIFY command makes it possible to alter a line without retyping the whole line, e.g.

```
COMMAND?  mod  1795 (CR)
1795.  IF (R.EQ.18) GO TO 370
ALTERS?
```

Several types of alternatives may now be made to the line of text. After an alteration is made, WYLBUR will type a copy of the altered line and then prompt for further alterations.

In the following example the use of

delete   used by the letter d
insert   used by the letter i
replace   used by the letter r

will be demonstrated.

```
COMMAND?  mod  1795  (CR)
1795.  IF (R.EQ.18) GO TO 370
ALTERS?                      d (CR)
1795.  IF (R.EQ.18) GO TO 70
```

```
ALTERS?             d d(CR)
1795.  IF (R.EQ.18) GO 70
ALTERS?             i TO (CR)
1795.  IF (R.EQ.18) GO TO 70
ALTERS?          i.OR.R.EQ.12 (CR)
1795.  IF (R.EQ.18.OR.R.EQ.12) GO TO 70
ALTERS?          r7(CR)
1795.  IF (R.EQ.17.OR.R.EQ.12) GO TO 70
ALTERS?      rGT(CR)
1795.  IF (R.GT.17.OR.R.EQ.12) GO TO 70
ALTERS? (CR)
?
```

The user signals that he has made all alterations to the line by typing nothing into the ALTERS? line but a carriage return.

Note: Using (ATTN) instead of (CR) will cause WYLBUR to revert to the original version of the line.

V. To save the modifications just made to the working data set, the user must use the SAVE command as follows:

```
COMMAND?   save smodel (CR)
VOLUME?    tso002 (CR)
"SMODEL" SAVED ON TSO002
COMMAND?
```

As a result of this the working data set has been saved under the name SMODEL.

If the user wants to replace the original data set SOSMDL i.e., the SOSMDL should include the present alterations that have been made then do as follows:

```
COMMAND?  save sosmdl rep (CR)
VOLUME?   tso002 (CR)
"SOSMDL"  REPLACED ON TSO002
COMMAND?
```

VI. In order to get a listing of the program the following steps need to be done.

```
COMMAND?  mod 2
2.   //SO1  EXEC FORTGCLG,PARM.FORT='NOSOURCE,NOUST,NOMAP',
ALTERS?                d                                    d (CR)
2.   //SO1  EXEC FORTGCLG,
ALTERS (CR)
COMMAND?
```

VII. The user may ask WYLBUR to show the names of all data sets he has saved on any given volume.

```
COMMAND?  show dsn on tso002 (CR)
TSO002
 DEVEP
 DEVEP1
 SOSMDL
COMMAND?
```

VIII. The SCRATCH options allows a user to delet those data sets he no longer needs.

```
COMMAND?  scratch devep2 (CR)
"DEVEP2"  SCRATCHED ON TSO002
COMMAND?
```

APPENDIX - 6

MAINTAINING THE INITIAL SATISFACTION THRESHOLDS

In order to measure the effect in SOS-1 of raising the demand measure thresholds if the demand per capita is more than satisfied during the past two years--simulation of learned gratification levels--two additional runs of the model were made where the initial thresholds were maintained even if output surpassed required levels. These runs are:

RUN 8: comparable to RUN 1 (the base case)

RUN 9: comparable to RUN 4 (fund growth limited to 2.0%)

COMPARISON OF RUNS 1 AND 8

Run 1 is discussed in detail within the Model Test Section of this report. The major characteristics of that run to be considered within this analysis are:

Thresholds of measures were upgraded 79 times and reduced 0 times.

The price of silver became prohibitive in year 22 causing significant long term adjustment redistribution of investment funds.

The increased cost of suburban land contributed to the region's problems in year 23.

By year 25 the population had increased to 1.314 times the original and the combined QOL measure was 1.82.

In Run 8, the following results were noted:

Similar results to Run 1 are noted in that food and silver again depressed productivity.

As in Run 1, silver became a problem in year 22. However, even with the secondary food problem of cost increases by year 23 to 1.6 times the original level, short term adjustments continued to supplement production adequately for the region.

Run 8 never required lowering of QOL thresholds through year 25; however, it appeared adjustments to lower levels were imminent when the run was ended.

In summary, while differences occurred between Run 1 and Run 8, and the expected greater flexibility of adjustments did appear in Run 8; no major differences existed to select one set of output over the other if the simulation were continued past year 25.

COMPARISON OF RUNS 4 AND 9

The next two runs used investment funds set to an annual growth level of 2.0%. Neither run produced a major adjustment problem during the 25 year run. Comparison of population levels and individual measures of demand satisfaction at year 25 shows only minor variations. Comparison of unit costs for resources suggests that there is little difference again although Run 4 would be favored. Although the flexibility for adjustments appear higher for Run 9, this is not tested in the 25 year run and hence the relative merit is not measured.

FINDING

Although some short term merit is noted in the flexibility of adjustments introduced by maintaining per capita demand at constant threshold levels, the differences produced appear to be small for long term adjustments under heavy stress. If a system is well balanced to carrying capacity of a region this aspect may become important but no demonstration of this has been produced in SOS-1 runs to date.

APPENDIX - 7

SETTING POPULATION GROWTH TO ZPG

A set of analyses were performed setting the gross birth rate and death rate equal, thus causing all population change to be set by net immigration rates. The set of runs considered in the analysis of this appendix are:

RUN 10: all data same as RUN 1 except the birthrate

RUN 11: all data same as RUN 4 (2% funds growth) except the birthrate

RUN 12: all data same as RUN 5 (0% funds growth) except the birthrate.

COMPARATIVE DEMAND SATISFACTION

In the comparisons, the need to produce output was forced by the increasing demand thresholds even though the population sizes for the ZPG cases are much smaller than for the original cases. Figure 7-1 lists the population levels and demand satisfaction levels for each run at t=25. Then the product of these two statistics is provided.

	RUN					
	1	10	4	11	5	12
Population	1.314	1.056	1.279	1.028	1.143	.924
QOL Level	1.820	2.160	1.110	1.370	.865	1.104
Product	2.39	2.28	1.43	1.41	.99	1.02

FIGURE 7-1

COMPARATIVE DEMAND SATISFACTION LEVELS

In the third comparison (5 and 12) the combined satisfaction levels are similar; in both of these cases high unemployment has caused similar salary levels. In the other two comparisons a significant production drop has occurred due to the relative shortage of work units in the ZPG cases (10 and 11).

The question exists, however, which is preferable; a high QOL or a larger population? For the 0.0 funds growth case a significant drop in population has occurred from the initial situation suggesting that the ZPG alternative may have hidden detrimental effects. However, for the 2.0% funds comparison either run has output results that appear appropriate. Since the Run 4 case was selected the best parametric case in the analysis of the main report, an alternate population growth case may be appropriate as a "best" demand satisfaction case with the birth rate about 50% greater than the death rate--a case midway between Run 4 and Run 11.

While Run 10 has comparative data that suggests it has merit it caused the same problems that are discussed for Run 1 in the body of the report. Two major resource depletions have been caused by year 25, suggesting that the regional carrying capacity is significantly affected. Hence, it is not a viable alternative to Runs 4 or 11.

Case 11 was run again with the demand thresholds held constant to the initial run values. As has been noted in the cases discussed in Appendix 6, this apparent increase in adjustment flexibility produced no significant improvement over the Run 11 values.

FINDINGS

In the comparisons of present day population growth to ZPG under different fund levels, the general finding of the comparative analysis of the report body was maintained--best investment funds growth is about 2.0%. Also, the ZPG rate did not improve QOL as much as population size was lowered. Hence, while a lower birth rate may produce a better outcome, the rate is not as low as a ZPG rate.

APPENDIX - 8

REDUCTION OF SYSTEMIC ADJUSTMENTS OF SOS-1

The data base used for the Base Case of the model test incorporates a number of resource categories that, if no adjustments were allowed, would rapidly be critically depleted. These levels for the initial reserve stockpile of nonrenewable resources are based on the generally accepted static stockpile sizes that are documented in several sources. Figure 8-1 provides a list of the expected length of availability at the initial usage rates.

Iron	50 yrs	Silver	5 yrs *
Copper	30 yrs	Trace Metals	100 yrs
Zinc/Lead	25 yrs	Coal	250 yrs
Mercury	8 yrs	Oil	20 yrs

FIGURE 8-1

Expected Life of Static Resource Levels

The SOS-1 model includes the capability to adjust stockpile reserves as a function of unit costs, and to increase procurement funds available for resource purchases. A fully operating version of this is Run 1; the Base Case, 25 year output is completely reproduced as Appendix 9.

During its run, adjustments were made as follows:

Stockpile increases -19
Resource substitutions -9
Years in which imports were made -19
Years in which funds were adjusted -3.

To determine if the model would react similar to other models that do not include these adjustment mechanisms and to determine the selective effects of elimination of some adjustments, a set of SOS-1 runs were made in which major portions of the model were systematically removed. This appendix documents the effects of three such runs; all exactly comparable to the Base Case run.

RUN 13 removed all adjustments

RUN 14 allowed only long term funds reallocation

---

*Later data suggest 11 years.

RUN 15 allowed long term and resource adjustment
but no short term adjustments.

RUN 13: THE RIGID DESCRIPTIVE SYSTEM

Within Run 13 the only adjustments in the use of data are the changes in unit costs for resources as the available stocks are consumed. Thus it can be anticipated that components that use critical resources will use somewhat less amounts each year until the stock is depleted; then the production of that component will be reduced to a negligible level. Since the two resources in shortest supply are silver (statically 5 years) and mercury (8 years), the using components--health, heavy polluting manufacture and commercial for silver; health, both manufacturing components, agriculture and household and recreation for mercury--should fail inside the first decade. Figures 8-2 and 8-3 provide the output histories for all ten components.

In year 2, the first major effect on production was an increase in salaries per work unit, causing most output levels to drop to 75-85 percent of the first year levels in year 3. By year 5 nearly full recovery had been made.

In year 6, the stocks of silver were 98% depleted and for mercury were 93% depleted. In year 7, the components of health and heavy polluting industries dropped to one-fifth the initial production level. By year 8, three components that require silver ceased production. In year 9, escalating unit costs for mercury reduced outputs for light polluting manufacture, agriculture and household to negligible levels.

Thus the model reacted as anticipated under the no adjustment case. If a rigid, no adjustment system is used, the model reacts as predicted.

RUN 14: FUNDS REALLOCATION ONLY

Run 14 differed from Run 13 only in the area of allowing long term allocations to occur as soon as an economic justification was provided. Thus the expected reaction to a resource shortage would be shifting of funds to the components affected by the shortage, thus allowing them to pay higher unit costs. The result should be a system collapse that occurs somewhat faster than in Run 13.

This was realized; by year 6 silver costs escalated putting the outputs of the affected components at negligible levels in year 7. The heavy shifting of funds to compensate

TABLE NUMBER TWO - PUBLIC SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	EDUCATION (E)	TRANSPORTATION (T)	HEALTH (H)	DEFENSE AND OTHER (D)	WELFARE (W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0819	1.0328	1.0906	1.0500	1.0880
3.	0.8308	0.7644	0.8573	0.7785	0.8323
4.	1.0479	0.9207	1.0869	0.9560	1.0586
5.	1.1346	0.9520	1.1954	1.0042	1.1529
6.	1.2219	0.9843	1.2752	1.0545	1.2457
7.	1.3085	1.0171	0.2315	1.1045	1.3415
8.	1.4091	1.0501	0.0000	1.1530	1.4501
9.	1.5154	1.0840	0.0000	1.2038	1.5665
10.	1.6311	1.1186	0.0000	1.2573	1.6936
11.	1.7565	1.1547	0.0000	1.3135	1.8320
12.	1.8919	1.1916	0.0000	1.3725	1.9826
13.	2.0473	1.2314	0.0000	1.4411	2.1585
14.	2.2047	1.2707	0.0000	1.5053	2.3353
15.	2.3761	1.3112	0.0000	1.5739	2.5297
16.	2.5669	1.3530	0.0000	1.6458	2.7497
17.	2.7759	1.3961	0.0000	1.7219	2.9909
18.	3.0006	1.4406	0.0000	1.8076	3.2523
19.	2.9857	1.3687	0.0000	1.7410	3.2487
20.	3.3870	1.4749	0.0000	1.9170	3.7204
21.	2.2382	0.9358	0.0000	1.2185	2.4438
22.	3.0215	1.2001	0.0000	1.6096	3.3391
23.	3.2895	1.2420	0.0000	1.6922	3.6645
24.	3.5797	1.2849	0.0000	1.7849	4.0203
25.	3.8770	1.3291	0.0000	1.8816	4.3756

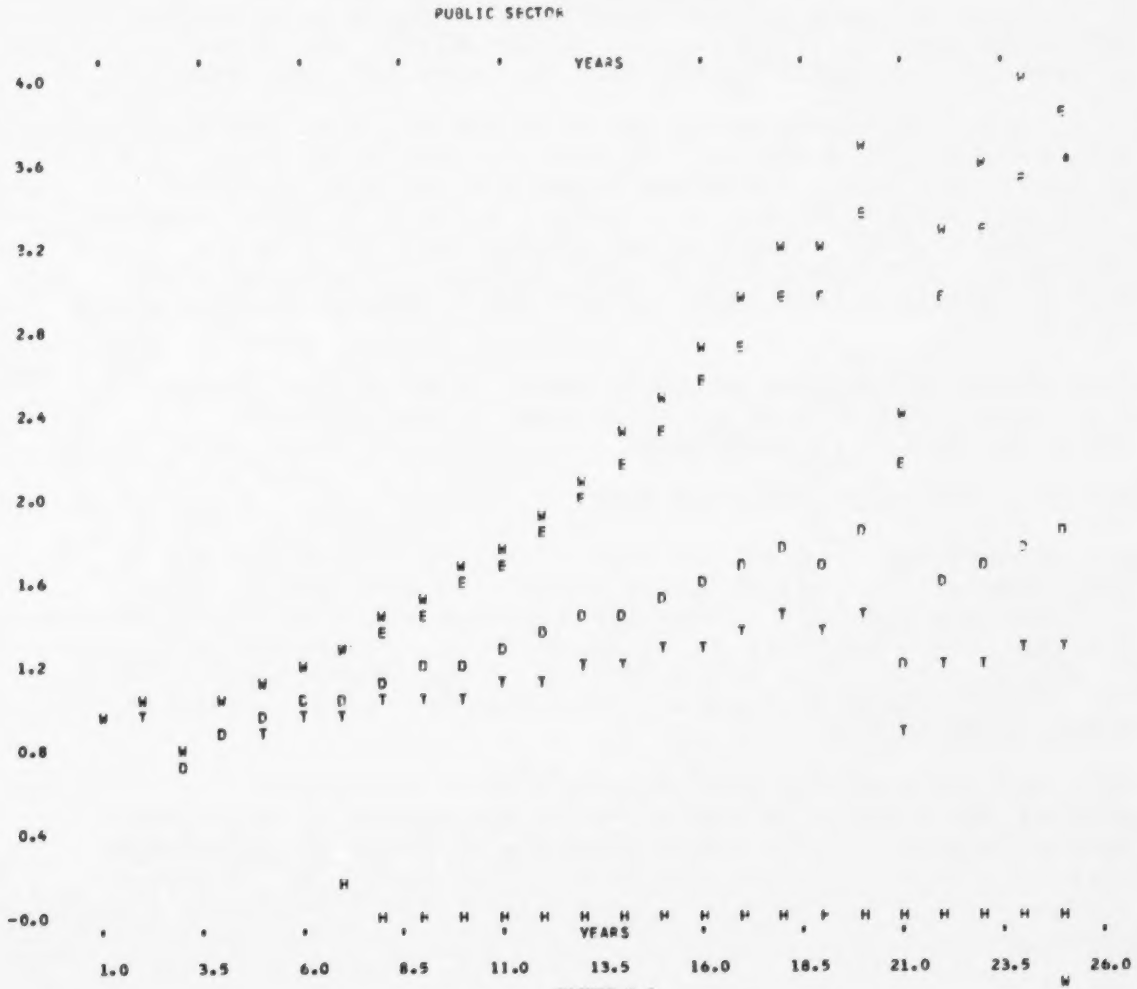

FIGURE 8-2
RUN 13 PUBLIC SECTOR OUTPUT DATA

TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	HEAVY POLL. MANUFACTURE (H)	LIGHT POLL. MANUFACTURE (L)	COMMERCIAL (C)	AGRICULTURE (F)	HOUSEHOLD & RECREATION (R)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0398	1.0454	1.0208	1.0005	1.0358
3.	0.8034	0.8118	0.7485	0.8443	1.0639
4.	0.9615	0.9720	0.8900	0.9202	1.0989
5.	1.0035	1.0166	0.9096	0.9229	1.1323
6.	1.0401	1.0622	0.9289	0.9255	1.1673
7.	0.2280	1.0971	0.7436	0.9258	1.2023
8.	0.0000	1.1172	0.0000	0.9251	1.2366
9.	0.0000	0.0063	0.0001	0.0316	0.0365
10.	0.0000	0.0017	0.0001	0.0082	0.0098
11.	0.0000	0.0012	0.0001	0.0058	0.0072
12.	0.0000	0.0008	0.0001	0.0037	0.0047
13.	0.0000	0.0006	0.0001	0.0027	0.0036
14.	0.0000	0.0005	0.0001	0.0020	0.0028
15.	0.0000	0.0004	0.0001	0.0016	0.0023
16.	0.0000	0.0003	0.0001	0.0013	0.0019
17.	0.0000	0.0003	0.0001	0.0011	0.0017
18.	0.0000	0.0003	0.0001	0.0009	0.0014
19.	0.0000	0.0002	0.0001	0.0008	0.0013
20.	0.0000	0.0002	0.0001	0.0006	0.0011
21.	0.0000	0.0002	0.0001	0.0006	0.0010
22.	0.0000	0.0002	0.0001	0.0005	0.0009
23.	0.0000	0.0002	0.0001	0.0004	0.0008
24.	0.0000	0.0001	0.0001	0.0004	0.0008
25.	0.0000	0.0001	0.0001	0.0003	0.0007

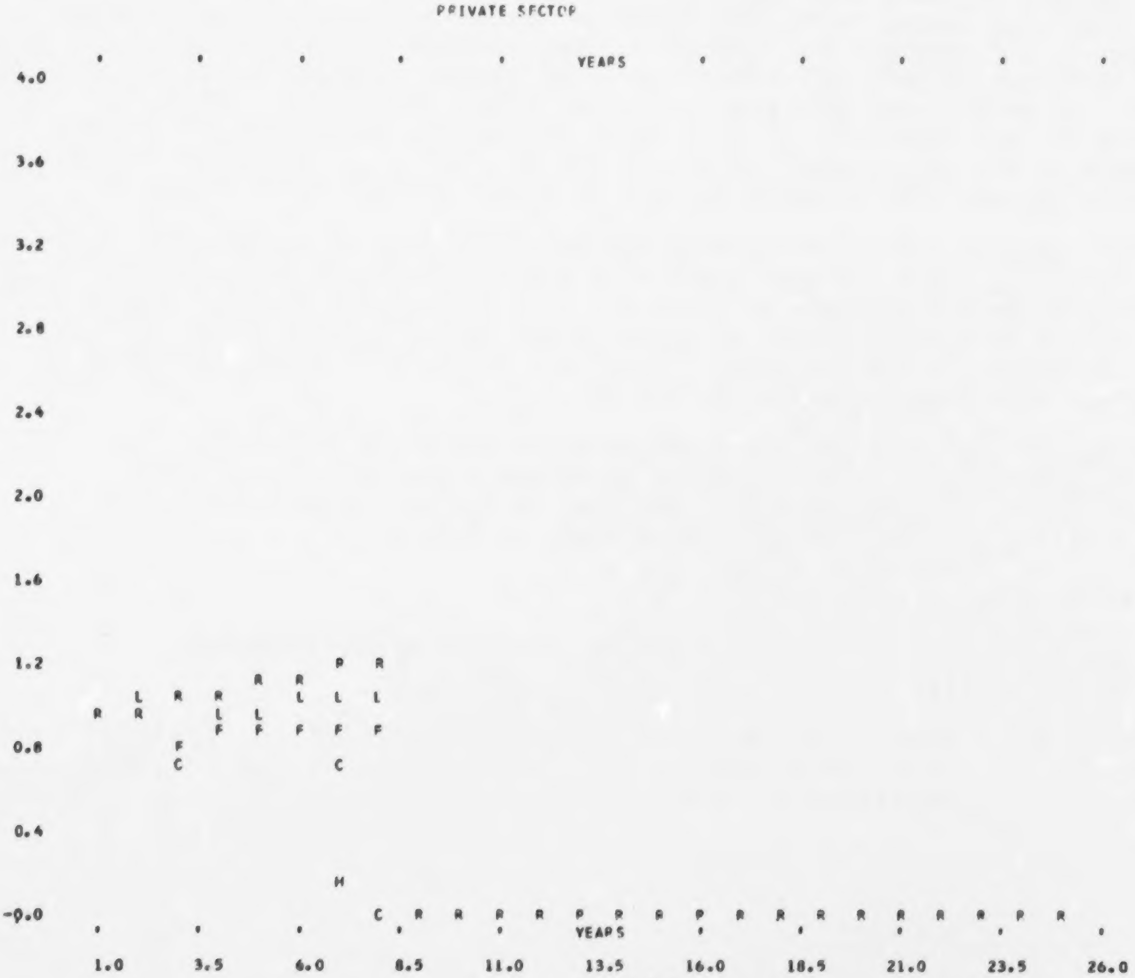

FIGURE 8-3
RUN 13 PRIVATE SECTOR OUTPUT DATA

this shortfall reduced the pressure on mercury usage so that its affected components did not collapse until year 10. However, by year 10, shifting of funds and resource outages reduced 7 of the production output components to negligible output levels as predicted.

RUN 15: NO SHORT TERM SMOOTHING ADJUSTMENTS

Run 15 allowed all types of resource adjustments and long term production and funds adjustments but did not allow short term marginal compensations for minor, local deficiencies. As such its output should be similar to Run 1 in that all components should continue reasonable production, but different in that very ragged production trends should be produced due to overreaction to local problems.

This did occur; as early as year 1 major changes were introduced that did not occur in Run 1 until year 22.

The set of long-term adjustments in Run 1 occur only after all short-term adjustment mechanisms have been exhausted; hence all changes in component input-output functions are conservative and all funds rates of growth changes occur only after more local changes have been found deficient. Thus in Run 1 (see Appendix 9) only four components adjusted the input-output formulas, each once and all in year 22. Also, in years 22, 23, and 24, redistribution of funds growth rates occurred.

The removal of short-term adjustments in Run 15 produced many long term changes beginning with both funds changes and input-output changes in year 1. Six components changed input-output formulas; three of them twice; two of which were reversals to the original formulas. Long term funds reallocation occurred 11 times in Run 14.

Figures 8-4 through 8-7 provide data for runs 1 and 15 on public and private output patterns. The effect of lack of short term adjustments for Run 15 are quite apparent; the patterns are much more ragged than in Run 1.

FINDINGS

The model components are causing results as anticipated in the design of SOS-1:

- Removal of resource adjustments causes the regional production systems to rapidly collapse due to rapid depletion of scarce natural resources.

TABLE NUMBER TWO - PUBLIC SECTOR CUTPLT UNITS
(SCALEC TO ORIGINAL VALUE)

YEAR	EDUCATICN (E)	TRANSPORTATICN (T)	HEALTH (H)	DEFENSE AND OTHER (C)	WELFARE (W)
1.	1.0000	1.000C	1.C000	1.C000	1.0000
2.	1.0819	1.0328	1.0906	1.0500	1.0880
3.	0.8308	0.7644	0.8580	0.7785	0.8323
4.	1.0294	0.8803	1.0657	C.5560	1.0313
5.	1.1146	0.9102	1.2039	1.0042	1.1232
6.	1.2245	0.9411	1.2963	1.C546	1.2503
7.	1.3089	C.9725	1.3892	1.1047	1.3411
8.	1.0417	0.7438	1.1412	0.8479	1.0668
9.	1.2768	0.8846	1.4066	1.0285	1.3073
10.	1.3841	0.9150	1.5858	1.0800	1.4629
11.	1.5167	0.9459	1.7046	1.1329	1.5792
12.	1.2167	0.7305	1.4119	C.88C8	1.2700
13.	1.4933	0.8662	1.7571	1.0699	1.5601
14.	1.6485	0.8956	1.9858	1.1227	1.7466
15.	1.7770	0.9256	2.1573	1.1780	1.8884
16.	1.9202	0.9572	2.3750	1.2331	2.0507
17.	2.0804	C.9893	2.6183	1.2900	2.2355
18.	2.2519	1.0226	2.8810	1.3544	2.4312
19.	2.4292	1.0575	3.1468	1.4162	2.6343
20.	2.6208	1.0921	3.4425	1.4815	2.8559
21.	2.8337	1.1274	3.7936	1.5500	3.1090
22.	3.0668	1.1640	2.3828	1.6245	3.3811
23.	3.3602	1.2017	4.4899	1.6996	3.8465
24.	3.7345	1.2407	4.9685	1.7789	5.8451
25.	4.2434	1.2807	5.4544	1.8621	6.1298

PUBLIC SECTOR

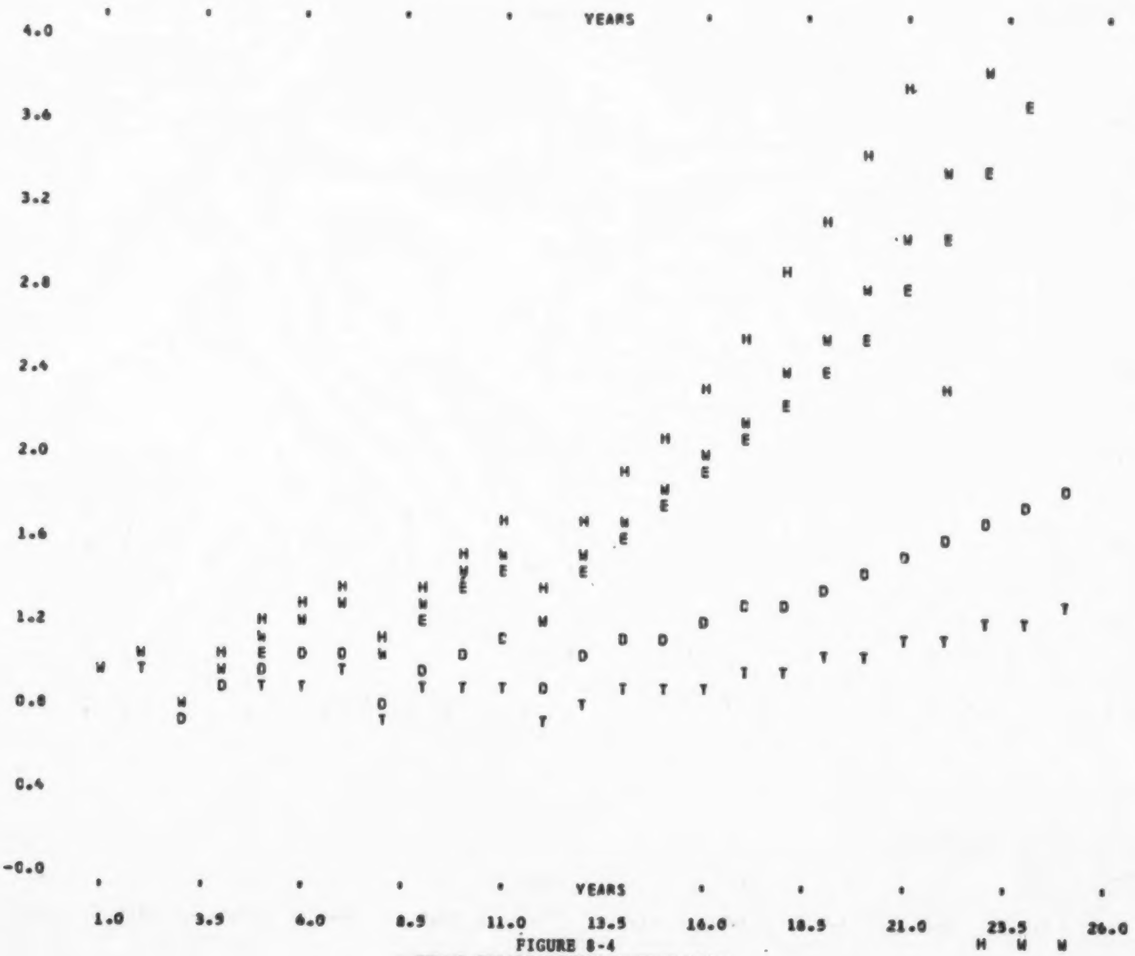

FIGURE 8-4
RUN 1 PUBLIC SECTOR OUTPUT DATA

TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	HEAVY POLL. MANUFACTURE (H)	LIGHT POLL. MANUFACTURE (L)	COMMERCIAL (C)	AGRICULTURE (F)	HOUSEHOLD & RECREATION (R)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0398	1.0454	1.0208	1.0005	1.0358
3.	0.8039	0.8118	0.7486	0.8443	1.0639
4.	0.9403	0.9378	0.8581	0.9202	1.0989
5.	0.9872	0.9814	0.8771	0.9229	1.1323
6.	1.0352	1.0267	0.8944	0.9286	1.1676
7.	1.0752	1.0658	0.9132	0.9263	1.2027
8.	0.8796	0.8810	0.6939	0.7850	1.2400
9.	1.0230	1.0123	0.8143	0.8379	1.2811
10.	1.0689	1.0602	0.8324	0.8407	1.3221
11.	1.1104	1.1042	0.8492	0.8424	1.3635
12.	0.9119	0.9146	0.6504	0.7095	1.4093
13.	1.0658	1.0538	0.7636	0.7740	1.4640
14.	1.1103	1.1022	0.7809	0.7767	1.5160
15.	1.1591	1.1520	0.7986	0.7790	1.5720
16.	1.2339	1.2426	0.8169	0.7814	1.6321
17.	1.2802	1.2874	0.8369	0.7836	1.6922
18.	1.3405	1.3452	0.8559	0.7862	1.7539
19.	1.3952	1.4007	0.8753	0.7886	1.8210
20.	1.4524	1.4578	0.8958	0.7907	1.8879
21.	1.5111	1.5168	0.9153	0.7709	1.8096
22.	1.0064	1.5818	0.8956	0.6589	1.4671
23.	1.6765	1.5663	0.9840	0.7102	1.4063
24.	1.7400	1.6719	1.0342	0.7538	1.5241
25.	1.8318	1.7103	1.0827	0.7861	1.5835

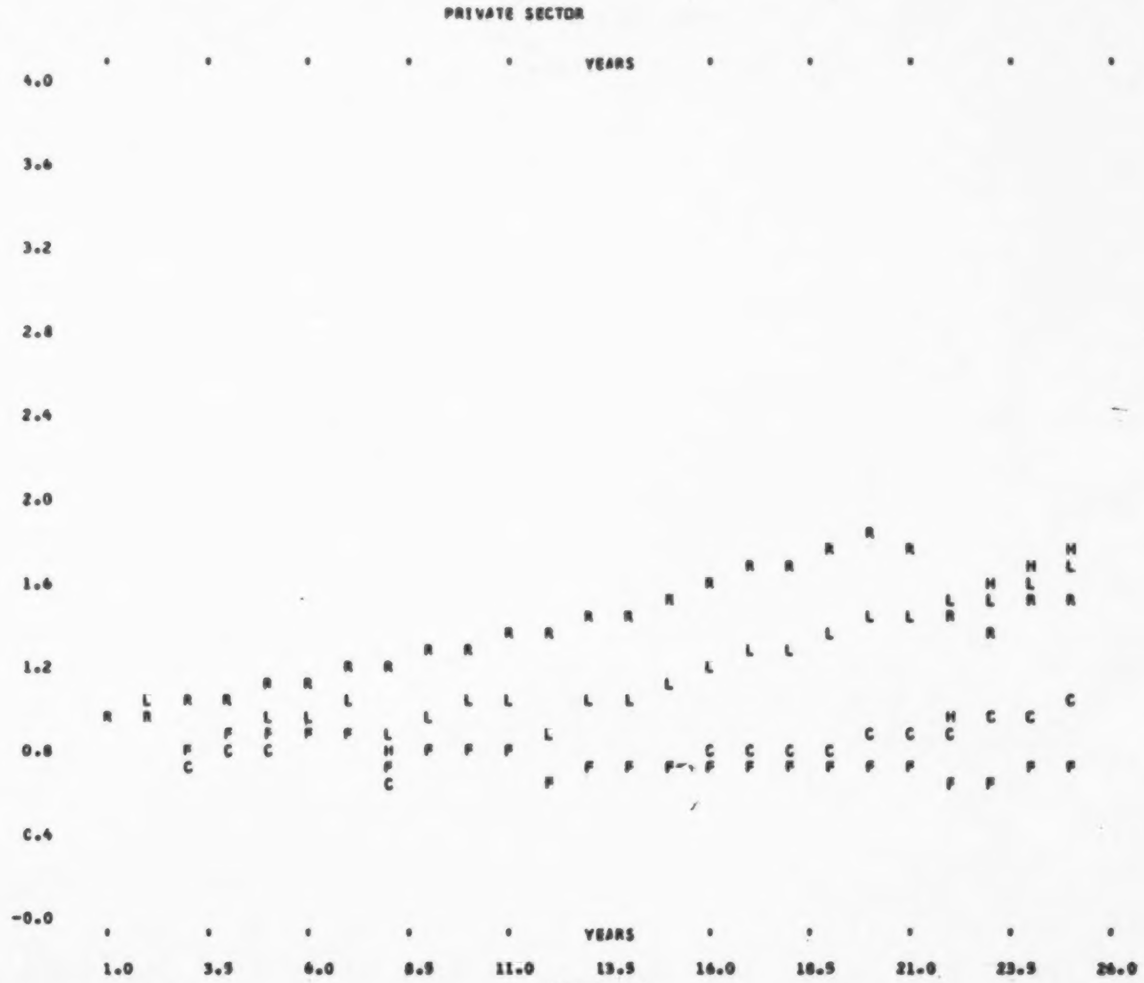

FIGURE 8-5
RUN 1 PRIVATE SECTOR OUTPUT DATA

TABLE NUMBER TWO - PUBLIC SECTOR OUTPUT UNITS (SCALED TO ORIGINAL VALUE)

YEAR	EDUCATION (E)	TRANSPORTATION (T)	HEALTH (H)	DEFENSE AND OTHER (D)	WELFARE (W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0985	1.0328	1.0906	1.0500	1.1407
3.	0.8685	0.7653	0.8570	0.7792	1.2143
4.	1.1505	0.9213	1.0924	0.9565	1.5258
5.	1.3275	0.9527	1.1930	1.0038	1.9182
6.	1.5132	0.9850	1.2333	1.0490	2.1352
7.	1.7626	1.0182	1.3345	2.5638	4.0087
8.	1.9834	1.0516	1.3886	2.2088	3.6700
9.	2.2909	1.0863	1.5400	2.3562	4.0748
10.	2.6790	1.1217	1.7503	2.5314	4.5848
11.	2.9453	1.1573	1.8961	2.6930	4.8941
12.	3.1874	1.1953	2.0800	2.8312	5.3129
13.	2.4948	0.8582	1.6606	2.0983	4.2624
14.	3.1834	1.0471	2.1479	2.6196	4.4412
15.	3.4729	1.0789	2.3621	2.7598	2.3776
16.	3.0578	0.8927	2.1127	2.3434	2.1394
17.	3.7020	1.0260	2.5872	2.7494	2.1598
18.	15.7182	1.0607	2.8383	3.2165	2.3846
19.	47.6771	0.0946	3.0965	1.7013	5.0356
20.	14.1677	0.3692	3.0676	1.7302	5.0903
21.	8.8037	0.6364	3.1439	1.7401	5.2333
22.	5.7611	1.0956	3.1776	1.7637	5.3222
23.	4.0363	1.8652	3.2308	1.7948	5.4528
24.	2.9890	3.1598	3.2524	1.8127	5.4791
25.	1.8847	5.3490	3.2959	1.8328	5.5337

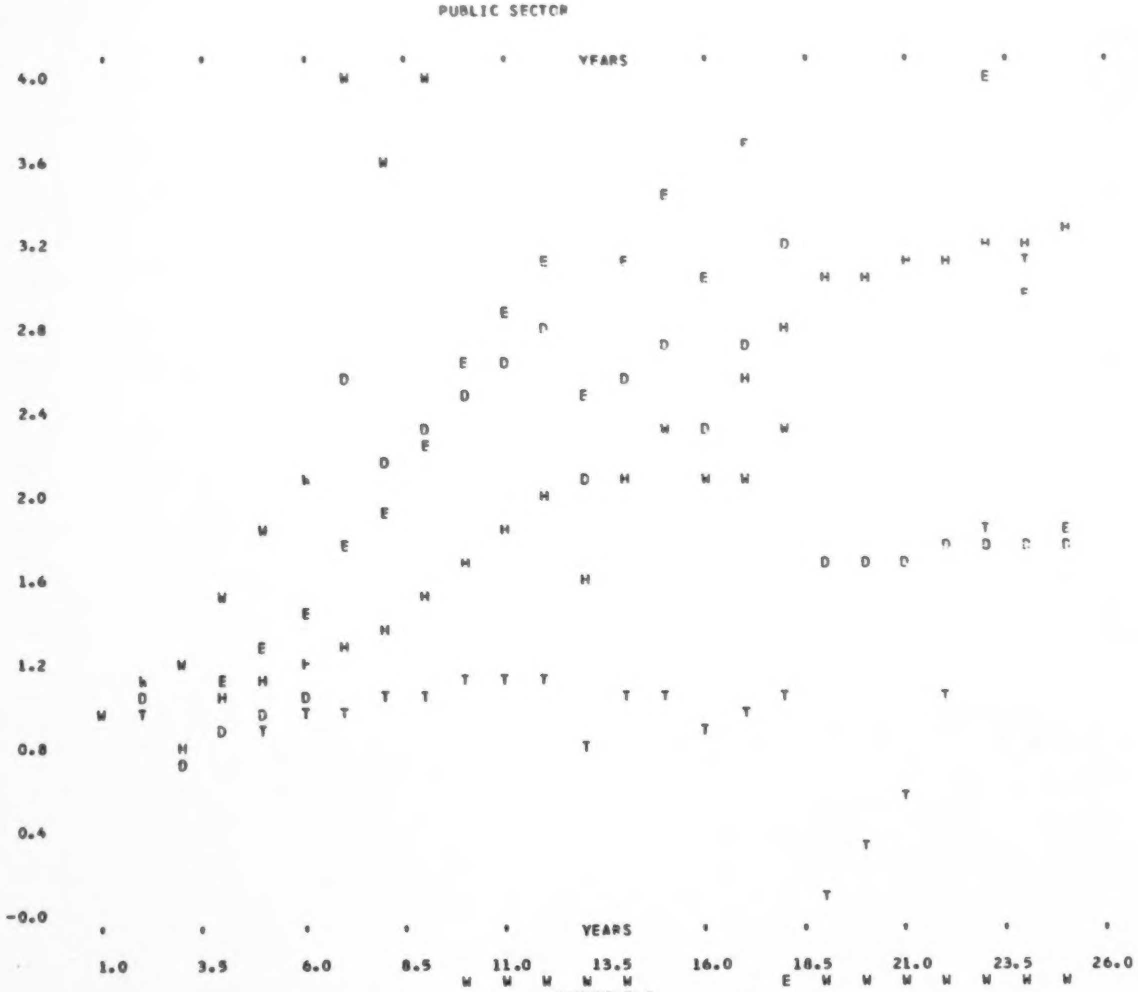

FIGURE 8-6
RUN 15 PUBLIC SECTOR OUTPUT DATA

TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	HEAVY POLL. MANUFACTURE (H)	LIGHT POLL. MANUFACTURE (L)	COMMERCIAL (C)	AGRICULTURE (F)	HOUSEHOLD & RECREATION (R)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0417	1.0443	1.0205	1.0084	1.0350
3.	0.8136	0.8103	0.7485	0.8560	1.0622
4.	0.9893	0.9791	0.8858	0.9411	1.0848
5.	1.0478	1.0300	0.8992	0.9508	1.1070
6.	1.0798	1.0637	0.9038	0.9556	1.1263
7.	1.1253	1.1118	0.9164	0.9646	1.1501
8.	1.1497	1.1384	0.9211	0.9686	1.1698
9.	1.2059	1.2057	0.9405	0.9818	1.1976
10.	1.2713	1.2952	0.9704	1.0009	1.2288
11.	1.3251	1.3555	0.9886	1.0128	1.2546
12.	1.3871	1.4252	1.0079	1.0234	1.2854
13.	1.0700	1.0978	0.7250	0.8440	1.3239
14.	1.3313	1.3500	0.8737	0.9425	1.3562
15.	1.3760	1.4140	0.8908	0.9522	1.3896
16.	1.1958	1.2242	0.7313	0.8443	1.4236
17.	1.4039	1.4253	0.8320	0.9116	1.4577
18.	1.4679	1.5082	2.2213	0.7658	2.0782
19.	0.4047	0.4126	0.5861	0.6192	0.8750
20.	0.7432	0.7448	0.8983	0.8810	1.1795
21.	0.8824	0.8851	0.8559	0.7334	1.1871
22.	1.0416	1.0446	0.8119	0.6021	1.1981
23.	1.2208	1.2273	0.7756	0.5051	1.2129
24.	1.4103	1.4303	0.7501	0.4352	1.2311
25.	1.6309	1.6639	0.7341	0.3891	1.2498

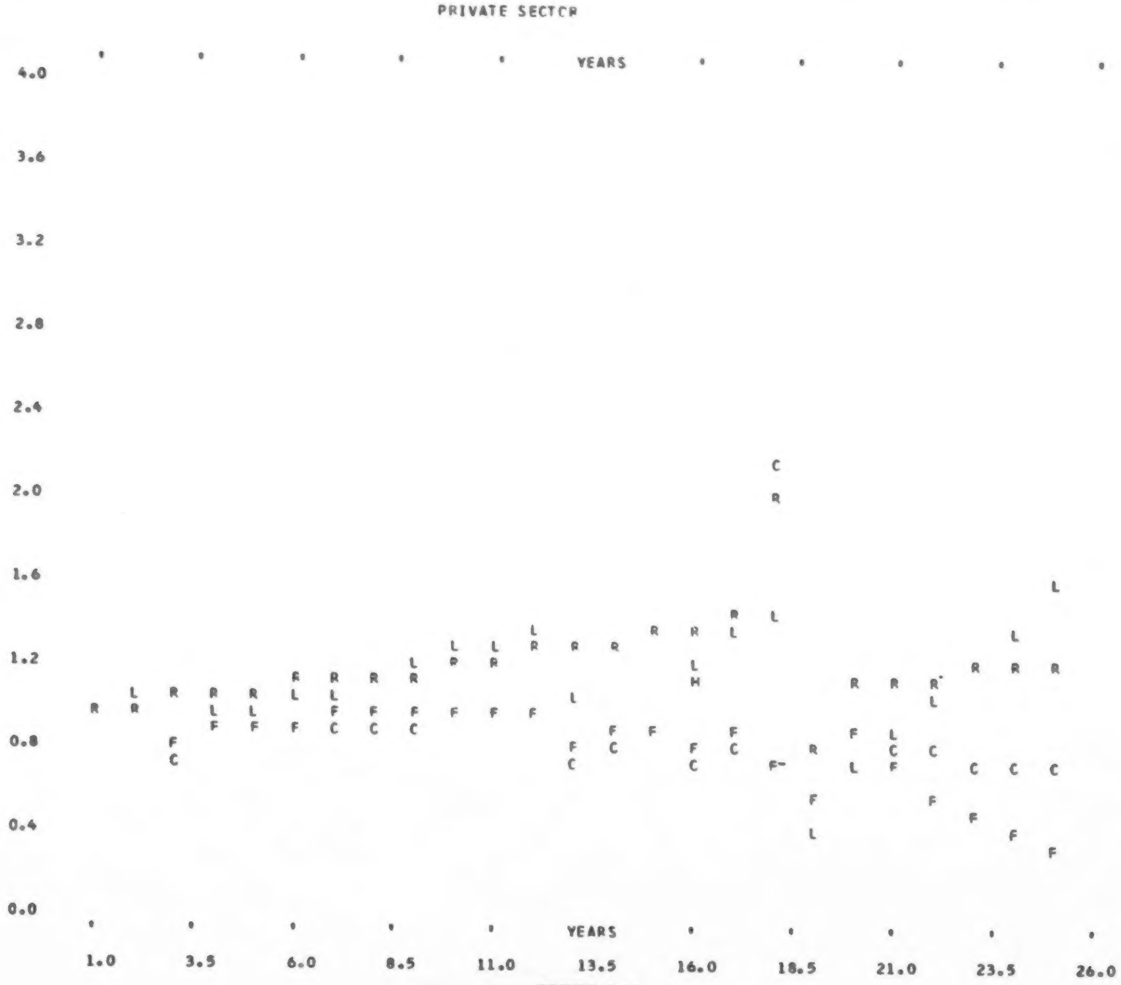

FIGURE 8-7
RUN 15 PRIVATE SECTOR OUTPUT DATA

- Provision of long term funds redistribution without resource availability adjustments hastened the rate of collapse since funds were shifted to purchase scarce goods driving their unit costs still higher.

- Inclusion of the resource adjustments and long term adjustments without short term adjustments to smooth reactions caused a system that remained reasonably viable for the run history but included ragged output trends, over-reaction to symptoms and much increased use of funds redistributions that led to introduction of new problems.

APPENDIX 9

LISTING OF ALL OUTPUT
FOR THE BASE CASE
(RUN 1)

```
                    *************************************************

                                   YEAR  IS     1

                    *************************************************


      ****STATE  OF  THE  SYSTEM****

                                                 ** REGIONAL POPULATION **

 AGE GROUP      POPULATION        EDUCATION     INSTITUTION      PRESCHOOL       NON-WORKER     PAID WORKER  UNPAID WORKER

   TOTAL        205424.875
   <18           69443.437        51243.730       474.636       17603.410         121.650          0.0            0.0
   18-24         25143.328         7929.703       223.787           0.0           453.032      14243.277      2293.543
   25-65         90123.312            0.0         573.024           0.0           745.634      65811.875     22992.766
   >65           20714.684            0.0        1262.007           0.0         19452.676          0.0            0.0

                                   ** COMPONENT OPERATING DATA  **

     COMPONENT               OPERATING    MAINT.     PRODUCTION    OUTPUT      CAPITAL    ANNUAL %
  NO.       NAME            FUNDS(1000$)  COST(%)   FUNDS(1000$)               % USED    EXPANSION
  1       EDUCATION           61565.785     2.00      60358.641    1000.0      100.0        0.0
  2 TRANSPORTATION            14475.992     5.00      13786.668    1000.0      100.0        0.0
  3          HEALTH           27474.973     3.00      26674.734    1000.0      100.0        0.0
  4   DEFENSE&OTHER          114029.875     3.00     110708.625    1000.0      100.0        0.0
  5         WELFARE          158086.250     3.00     153481.812    1000.0      100.0        0.0
  6   HVY POLLUTING          212959.750     3.00     206757.062    1000.0      100.0        0.0
  7   LGT POLLUTING          134933.937     4.00     129744.125    1000.0      100.0        0.0
  8      COMMERCIAL           44559.172     4.00      42845.355    1000.0      100.0        0.0
  9     AGRICULTURE           85254.937     2.00      83583.312    1000.0      100.0        0.0
  10     HOME & REC          304860.312     3.00     295980.937    1000.0      100.0        0.0

                                ** RESOURCE UTILIZATION DATA **

      RESOURCE              UTILIZATION          REMAINING    RECYCLE    THIS CYCLE
  NO.          NAME        USED IN YEAR   % USED STOCKPILE     RATIO     UNIT COST
   1           IRON            200.00      3.00    9700.00      0.0      0.00004902
   2         COPPER            250.00     27.50    7250.00      0.06     0.00006000
   3      LEAD,ZINC            320.00     23.20    7680.00      0.04     0.00001000
   4        MERCURY           1000.00     60.00    4000.00      0.36     0.00000110
   5         SILVER           1000.00     60.00    4000.00      0.22     0.00000329
   6    TRACE METAL            100.00      2.00    9800.00      0.0      0.00000790
   7           COAL             49.70     50.50    4950.30      0.0      0.00080901
   8            OIL            455.00      4.95    9505.00      0.0      0.00011000
   9    ELECTRICITY           4799.99     48.00    5200.01      0.0      0.00004580
   10                            0.0       0.00       0.0       0.0      0.0
   11        LUMBER            500.00      0.00    9999.99      0.00     0.00016700
   12          FOOD           7999.99      0.00    9999.99      0.0      0.00033000
   13                            0.0       0.0    10000.00      0.0      0.0
   14    URBAN LAND           6749.99     67.50    3250.01      0.0      0.00001846
   15 SUBURBAN LAND           4000.00     40.00    6000.00      0.0      0.00001816
   16   ARABLE LAND           7000.00     46.67    8000.00      0.0      0.00001822
   17                            0.0       0.00       0.0       0.0      0.0
   18    WORK UNITS          74599.81     93.19    5455.32      0.0      0.00010330
   19     AIR UNITS           4999.99     50.00    5000.01      0.0      0.0
   20   WATER UNITS           4999.99     50.00    5000.01      0.0      0.0

** SATISFACTION OF DEMANDS **
```

```
MEASURE     PRESENT      PRESENT
NUMBER       VALUE     RESILIENCE
   1        1.6899       0.3412
   2        0.4868       0.3908
   3        0.4868       0.2170
   4        0.4868       0.2170
   5        4.8139       0.3754
   6        0.4868       0.0818
   7        1.2491       0.0409
   8        0.4868       0.3908
   9        0.4868       0.6227
  10        1.2491       0.6655
  11        0.4868       0.3908
  12        0.0          0.0

      ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**


 SHORT TERM FUNCS ADJUSTMENTS

 COPPCNENT  MAINT.AMT    UNITS FRCM
   NUMBER    DEFERRED    FXPORT EAL.
 CUMULATIVE EXPORT BALANCE IS        53053.8906

 DEMAND THRESHOLD ADJUSTMENTS
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                    *******************************************

                                 YEAR IS    2

                    *******************************************

****STATE  OF  THE  SYSTEM****

                                  ** REGIONAL POPULATION **

AGE GROUP    POPULATION     EDUCATION    INSTITUTION     PRESCHOOL     NON-WORKER    PAID WORKER  UNPAID WORKER

  TOTAL      207507.125
   <18        69233.312     51088.684       473.200      17550.172       121.282          0.0           0.0
  18-24       25573.937      8065.504       227.620          0.0         460.791      14487.207      2332.824
  25-65       91411.250         0.0         581.213          0.0         756.290      66752.375     23321.355
   >65        21288.422         0.0        1296.962          0.0       19991.473          0.0           0.0

                              ** COMPONENT OPERATING DATA  **

       COMPONENT             OPERATING    MAINT.    PRODUCTION    OUTPUT     CAPITAL    ANNUAL %
   NO.       NAME           FUNDS(1000$)  COST(%)  FUNDS(1000$)              % USED     EXPANSION
   1        EDUCATION         66614.125     2.00     65307.996     1081.9     100.0       4.02
   2 TRANSPORTATION           14968.164     5.00     14255.402     1032.8     100.0       1.63
   3           HEALTH         30194.965     3.00     29315.504     1090.6     100.0       4.43
   4   DEFENSE&OTHER         119731.250     3.00    116243.937     1050.0     100.0       2.47
   5          WELFARE        171997.687     3.00    166988.062     1088.0     100.0       4.31
   6   HVY POLLUTING         222968.812     3.00    216474.625     1039.8     100.0       1.97
   7   LGT POLLUTING         141140.812     4.00    135712.312     1045.4     100.0       2.24
   8      COMMERCIAL          45539.441     4.00     43787.926     1020.8     100.0       1.04
   9     AGRICULTURE          85510.625     2.00     83833.937     1000.5     100.0       0.03
   10     HOME & REC         316444.687     3.00    307227.875     1035.8     100.0       1.77

                              ** RESOURCE UTILIZATION DATA **

       RESOURCE              UTILIZATION            REMAINING   RECYCLE    THIS CYCLE
   NO.       NAME          USED IN YEAR   % USED   STOCKPILE    RATIO     UNIT COST
   1         IRON              207.15      5.07     9492.85      0.0      0.00004909
   2       COPPER              260.10     29.96     7003.86      0.07     0.00006227
   3     LEAD,ZINC             333.39     26.40     7360.37      0.06     0.00001062
   4      MERCURY             1051.44     67.73     3226.88      0.46     0.00000110
   5.      SILVER             1063.33     68.74     3125.55      0.28     0.00000649
   6   TRACE METAL             105.41      3.05     9694.59      0.0      0.00000790
   7         COAL               51.81     51.02     4898.49      0.0      0.00082646
   8          OIL              514.19     10.09     8990.81      0.0      0.00011000
   9   ELECTRICITY            5058.52     50.59     4941.48      0.0      0.00004721
   10                            0.0       0.00        0.0       0.0      0.0
   11       LUMBER             518.58      0.00     9999.99      0.00     0.00016700
   12         FOOD            8229.84      0.00     9999.99      0.0      0.00033000
   13                            0.0       0.0     10000.00      0.0      0.0
   14   URBAN LAND            6975.89     69.76     3024.11      0.0      0.00001894
   15 SUBURBAN LAND           4141.43     41.41     5858.57      0.0      0.00001833
   16  ARABLE LAND            7003.66     46.69     7996.34      0.0      0.00001844
   17                            0.0       0.00        0.0       0.0      0.0
   18   WORK UNITS           78358.56     96.45     2881.00      0.0      0.00012439
   19    AIR UNITS            5181.11     51.81     4818.89      0.0      0.0
   20  WATER UNITS            5127.33     51.27     4872.67      0.0      0.0

** SATISFACTION OF DEMANDS **
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 MEASURE    PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1        1.8090      0.4357
    2        0.5157      0.4734
    3        0.4977      0.2443
    4        0.5256      0.3140
    5        5.1008      0.4574
    6        0.5024      0.1165
    7        1.2834      0.0695
    8        0.4920      0.4056
    9        0.4822      0.6072
   10        1.2316      0.6421
   11        0.4992      0.4262
   12        0.C         0.0

      ****ADJUSTMENTS  CF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE     SUBS.     STOCKPILE      YEAR
  NUMBER     NUMBER      INCREASE   COMPLETED
    4           4          0.0          7
    5           5          0.0          7
    4         0.0        2500.          7
    5         0.0        1000.          7

 SHORT TERM FUNCS ADJUSTMENTS

 COMPONENT  MAINT.AMT    UNITS FRCM
  NUMBER     DEFERFED    EXPORT BAL.
 CUMULATIVE EXPCRT BALANCE IS       115332.000

 DEMANC THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
 NUMBER     UPGRADE  DEGRADE
    1       1.6899    0.0
    2       0.4868    0.0
    3       0.4868    0.0
    4       0.4868    0.0
    5       4.8139    0.0
    6       0.4868    0.0
    8       0.4868    0.0
   11       0.4868    0.0
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                              YEAR  IS      3

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   ****STATE  OF  THE  SYSTEM****

                                            ** REGIONAL POPULATION **

 AGE GROUP      POPULATION      EDUCATION    INSTITUTION     PRESCHOOL       NON-WORKER    PAID WORKER  UNPAID WORKER

   TOTAL        209895.500
    <18          69157.625      51512.293       477.136      17044.484         123.726          0.0            0.0
   18-24         26042.211       8347.816       236.782          0.0           486.072      14628.926       2342.622
   25-65         92857.375          0.0         604.386          0.0           802.662      67887.312      23563.004
    >65          21838.066          0.0        1285.763          0.0         20552.305          0.0            0.0

                                   ** COMPONENT OPERATING DATA  **

      COMPONENT               OPERATING    MAINT.    PRODUCTION     OUTPUT    CAPITAL    ANNUAL %
 NO.         NAME           FUNDS(1000$)  COST($)  FUNDS(1000$)              % USED    EXPANSION
  1      EDUCATION            72076.437     3.02     69561.500      830.8      76.8        2.66
  2 TRANSPORTATION            15477.070     5.21     14710.359      764.4      74.0        1.08
  3         HEALTH            33184.234     5.73     31385.496      858.0      78.7        2.93
  4   DEFENSE&OTHER          125717.687     3.89    121009.625      778.5      74.1        1.64
  5        WELFARE           187133.312     4.41    179228.125      832.3      76.5        2.95
  6   HVY POLLUTING          233448.312     4.07    224328.000      803.9      77.3        1.31
  7   LGT POLLUTING          147633.187     4.90    140738.750      811.8      77.7        1.49
  8      COMMERCIAL           46541.277     4.59     44498.441      748.6      73.3        0.69
  9     AGRICULTURE           85767.062     2.01     84073.187      844.3      84.4        0.02
 10     HOME & REC           328469.312     3.91    316117.937     1063.9     100.0        2.09

                                 ** RESOURCE UTILIZATION DATA **

      RESOURCE            UTILIZATION              REMAINING    RECYCLE    THIS CYCLE
 NO.          NAME        USED IN YEAR    % USED  STOCKPILE     RATIO      UNIT COST
  1           IRON            160.96       6.68     9331.89      0.0      0.00004917
  2         COPPER            201.17      31.85     6815.38      0.08     0.00006560
  3      LEAD,ZINC            258.45      28.84     7115.57      0.07     0.00001123
  4        MERCURY            826.71      71.66     2902.46      0.51     0.00000110
  5         SILVER            761.40      73.96     2629.27      0.33     0.00000768
  6    TRACE METAL             97.59       4.03     9597.00      0.0      0.00000790
  7           COAL             41.28      51.43     4857.21      0.0      0.00084168
  8            OIL            411.58      14.21     8579.23      0.0      0.00011000
  9    ELECTRICITY           4003.81      40.04     5996.19      0.0      0.00004721
 10                             0.0        0.00        0.0       0.0      0.0
 11         LUMBER            478.38       0.00     9999.99      0.00     0.00016700
 12           FOOD           8155.95       0.00    10005.22      0.0      0.00033000
 13                             0.0        0.0     10000.00      0.0      0.0
 14     URBAN LAND           6495.62      64.96     3504.38      0.0      0.00001894
 15  SUBURBAN LAND           3804.88      38.05     6195.12      0.0      0.00001833
 16    ARABLE LAND           5910.16      39.40     9089.84      0.0      0.00001844
 17                             0.0        0.00        0.0       0.0      0.0
 18     WORK UNITS          59502.02      72.11    23014.16      0.0      0.00012439
 19      AIR UNITS           4200.49      42.00     5799.51      0.0      0.0
 20    WATER UNITS           4430.21      44.30     5569.79      0.0      0.0

 ** SATISFACTION OF DEMANDS **
 MEASURE     PRESENT      PRESENT
 NUMBER       VALUE     RESILIENCE
    1         1.3613     -0.1945
    2         0.3882     -0.2025
    3         0.3642     -0.2519
    4         0.4088     -0.1603
    5         3.7893     -0.2128
    6         0.3849     -0.2093
    7         0.9790     -0.1841
    8         0.3566     -0.2674
    9         0.4023      0.3408
   10         1.0232      0.3643
   11         0.5069      0.0413
   12         0.0         0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.     STOCKPILE     YEAR
   NUMBER    NUMBER      INCREASE  COMPLETED
     2          1           0.0         8
     2        0.0        5000.          8

  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT     UNITS FROM
   NUMBER     DEFERRED     EXPORT BAL.
     1         1441.53          0.0
     2          773.85          0.0
     3          995.53          0.0
     5         5614.00          0.0
     6         7003.45          1.76
     7         5905.32          0.0
     8         1861.65         51.61
  CUMULATIVE EXPORT BALANCE IS       133344.312

  DEMAND THRESHOLD ADJUSTMENTS
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                                    YEAR IS     4

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****STATE OF THE SYSTEM****

                                        ** REGIONAL POPULATION **

AGE GROUP      POPULATION      EDUCATION     INSTITUTION      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL        210165.312
  <18           68430.812      46985.250        441.585      20891.043         112.943          0.0            0.0
  18-24         26244.004       8135.125        234.900          0.0           476.737      14312.234       3085.013
  25-65         93391.750          0.0          586.095          0.0           743.079      62773.254      29289.320
  >65           22098.496          0.0         1286.369          0.0         20812.125          0.0            0.0

                              ** COMPONENT OPERATING DATA  **

    COMPONENT               OPERATING   MAINT.    PRODUCTION    OUTPUT    CAPITAL   ANNUAL %
NO.          NAME         FUNDS(1000$) COST(%)  FUNDS(1000$)             % USED   EXPANSION
1         EDUCATION         77986.687    4.79     74419.125    1029.4      95.1       1.99
2 TRANSPORTATION            16003.281   10.04     14543.059     880.3      85.2       0.81
3            HEALTH         36469.437    8.21     33700.980    1065.7      97.7       2.19
4   DEFENSE&OTHER          132003.437    3.76    127223.000     956.0      91.0       1.23
5           WELFARE        203600.875    7.05    190185.250    1031.3      94.8       2.13
6   HVY POLLUTING          244420.312    6.52    229465.500     940.3      90.4       0.98
7   LGT POLLUTING          154424.187    8.56    142249.375     937.8      89.7       1.12
8        COMMERCIAL         47565.152    8.35     43898.691     858.1      84.1       0.57
9       AGRICULTURE         86024.250    2.01     84327.437     920.2      92.0       0.01
10      HOME & REC         340950.812    4.56    326069.875    1098.9     100.0       2.39

                            ** RESOURCE UTILIZATION DATA **

     RESOURCE            UTILIZATION          REMAINING   RECYCLE   THIS CYCLE
NO.        NAME       USED IN YEAR   % USED STOCKPILE     RATIO     UNIT COST
 1           IRON         193.70      8.62    9138.19      0.0      0.00004929
 2         COPPER         225.91     32.38    7090.04      0.08     0.00006768
 3      LEAD,ZINC         302.77     31.68    6831.69      0.08     0.00001182
 4        MERCURY         606.47     66.40    3917.05      0.44     0.00000110
 5         SILVER         467.12     73.33    2843.69      0.32     0.00000820
 6    TRACE METAL         180.81      5.84    9416.20      0.0      0.00000790
 7           COAL          47.67     51.90    4809.54      0.0      0.00085636
 8            OIL         471.10     18.92    8108.12      0.0      0.00011000
 9    ELECTRICITY        4716.41     47.16    5283.59      0.0      0.00004721
10                          0.0       0.00       0.0       0.0      0.0
11         LUMBER         513.25      0.00    9999.99      0.00     0.00016700
12           FOOD        8505.17      0.00   10005.22      0.0      0.00033000
13                          0.0       0.0    10000.00      0.0      0.0
14     URBAN LAND        6908.98     69.09    3091.02      0.0      0.00001894
15 SUBURBAN LAND         4083.96     40.84    5916.04      0.0      0.00001833
16    ARABLE LAND        6441.24     42.94    8558.76      0.0      0.00001844
17                          0.0       0.00       0.0       0.0      0.0
18     WORK UNITS       70915.00     92.00    6170.44      0.0      0.00012439
19      AIR UNITS        4740.04     47.40    5259.96      0.0      0.0
20    WATER UNITS        4858.95     48.59    5141.05      0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT      PRESENT
 NUMBER     VALUE      RESILIENCE
    1       1.8073       0.0695
    2       0.4740      -0.0263
    3       0.4188      -0.1396
    4       0.5071       0.0416
    5       4.6572      -0.0326
    6       0.4468      -0.0821
    7       1.2182       0.0152
    8       0.4083      -0.1612
    9       0.4378       0.4594
   10       1.1937       0.5916
   11       0.5229       0.0741
   12       0.0          0.0

         ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE     SUBS.     STOCKPILE      YEAR
  NUMBER     NUMBER      INCREASE   COMPLETED
    3          0.0        5000.          9

 SHORT TERM FUNDS ADJUSTMENTS

 COMPONENT  MAINT.AMT     UNITS FROM
   NUMBER    DEFERRED     EXPORT BAL.
      1       1559.73           0.0
      2        800.16           0.0
      5       6108.02           0.0
      6       7332.61           0.0
      7       6176.96           0.0
      8       1902.61           0.0
 CUMULATIVE EXPORT BALANCE IS       160465.125

 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
  NUMBER     UPGRADE  DEGRADE
    9        0.4023    0.0
   10        1.0232    0.0
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                                         YEAR IS     5

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       ****STATE OF THE  SYSTEM****

                                                  ** REGIONAL POPULATION **

AGE GROUP      POPULATION       EDUCATION     INSTITUTION      PRESCHOOL      NON-WORKER    PAID WORKER  UNPAID WORKER

  TOTAL        212150.625
  <18           67686.250       48865.711         456.770      18245.441         118.335         0.0            0.0
  18-24         27325.969        8802.309         254.438          0.0           524.393     14916.203       2828.634
  25-65         94677.062           0.0           630.152          0.0           824.300     66139.375      27083.227
  >65           22501.164           0.0          1259.216          0.0         21241.961         0.0            0.0

                                         ** COMPONENT OPERATING DATA  **

     COMPONENT                 OPERATING     MAINT.    PRODUCTION      OUTPUT     CAPITAL    ANNUAL %
  NO.       NAME            FUNDS(1000$)   COST(%)   FUNDS(1000$)                  % USED    EXPANSION
  1       EDUCATION            84381.562      4.72      80576.562      1114.6      100.0        2.19
  2 TRANSPORTATION             16547.383     10.03      15038.441       910.2       88.1        0.65
  3          HEALTH            40075.875      5.26      38076.578      1203.9      100.0        3.78
  4   DEFENSE&OTHER           138603.500      3.72     133630.500      1004.2       95.6        0.98
  5         WELFARE           221517.562      6.95     207124.375      1123.2      100.0        2.35
  6   HVY POLLUTING           255908.000      6.49     240316.375       987.2       94.9        0.78
  7   LGT POLLUTING           161527.625      8.53     148837.125       581.4       93.9        0.89
  8      COMMERCIAL            48611.555      8.34      44868.344       877.1       85.9        0.41
  9     AGRICULTURE            86282.250      2.01      84580.437       922.9       92.2        0.01
  10     HOME & REC           353906.625      5.33     335989.437      1132.3      100.0        2.52

                                    ** RESOURCE UTILIZATION DATA **

       RESOURCE             UTILIZATION            REMAINING    RECYCLE     THIS CYCLE
  NO.        NAME        USED IN YEAR    % USED STOCKPILE      RATIO       UNIT COST
   1         IRON            246.62      11.05     8891.37      0.0        0.00004948
   2       COPPER            181.23      26.76     9752.57      0.05       0.00006768
   3    LEAD,ZINC            318.67      33.03     7021.31      0.09       0.00001237
   4      MERCURY            646.52      70.25     3468.36      0.49       0.00000110
   5       SILVER            505.25      76.94     2458.67      0.36       0.00000834
   6  TRACE METAL            194.34       7.78     9221.86      0.0        0.00000790
   7         COAL             50.11      52.41     4759.43      0.0        0.00087265
   8          OIL            492.48      23.84     7615.64      0.0        0.00011000
   9  ELECTRICITY           5016.83      50.17     4983.17      0.0        0.00004721
  10                           0.0        0.00        0.0       0.0        0.0
  11       LUMBER            530.75       0.00     9999.99      0.00       0.00016700
  12         FOOD           8723.25       0.00    10005.22      0.0        0.00033000
  13                           0.0        0.0     10000.00      0.0        0.0
  14   URBAN LAND           7118.37      71.18     2881.63      0.0        0.00001898
  15 SUBURBAN LAND          4219.82      42.20     5780.18      0.0        0.00001834
  16  ARABLE LAND           6460.17      43.07     8539.83      0.0        0.00001844
  17                           0.0        0.00        0.0       0.0        0.0
  18   WORK UNITS          74827.62      92.32     6227.94      0.0        0.00012439
  19    AIR UNITS           4927.00      49.27     5073.00      0.0        0.0
  20  WATER UNITS           4989.52      49.90     5010.48      0.0        0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT      PRESENT
 NUMBER     VALUE     RESILIENCE
    1       1.8528      0.0964
    2       0.5036      0.0344
    3       0.4290     -0.1188
    4       0.5673      0.1655
    5       4.9460      0.0274
    6       0.4639     -0.0471
    7       1.2143      0.0120
    8       0.4133     -0.1509
    9       0.4349      0.0812
   10       1.1386      0.1128
   11       0.5336      0.0962
   12       0.0         0.0

       ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**


  SHORT TERM FUNDS ADJUSTMENTS

  COMPCNENT  MAINT.AMT    UNITS FRCM
    NUMBER    DEFERRED    EXPORT BAL.
      2         827.37          0.0
      6        7677.24          0.C
      7        6461.10          0.0
      8        1944.46          0.C
  CUMULATIVE EXPORT BALANCE IS       165274.937

  DEMAND THRESHOLD ADJUSTMENTS

  MEASURE       NEW VALUE
   NUMBER    UPGRADE  DEGRADE
     4        0.5071   0.0
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                                       YEAR  IS      6

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    ****STATE  OF  THE  SYSTEM****


                                               ** REGIONAL POPULATION **

AGE GROUP       POPULATION        EDUCATION     INSTITUTION       PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL         214264.187
   <18           66985.000        48920.949         471.193       17473.086         119.779           0.0            0.0
   18-24         28417.152         9291.371         277.681           0.0           563.247       15410.340       2874.530
   25-65         96001.250            0.0           672.136           0.0           871.562       67364.187      27093.316
   >65           22860.738            0.0          1259.792           0.0         21600.941           0.0            0.0

                                 ** COMPONENT OPERATING DATA  **

     COMPONENT            OPERATING   MAINT.    PRODUCTION    OUTPUT     CAPITAL    ANNUAL %
 NO.        NAME         FUNDS(1000$) COST(%)  FUNDS(1000$)               % USED    EXPANSION
 1       EDUCATION         91300.812    3.13     88530.312    1224.5     100.0        3.43
 2 TRANSPORTATION          17109.984   10.03     15550.656     941.1      91.1        0.54
 3          HEALTH         44047.742    7.63     40925.852    1296.3     100.0        4.42
 4   DEFENSE&OTHER        145533.562    3.70    140347.250    1054.6     100.0        0.89
 5         WELFARE        241010.937    4.53    230559.000    1250.3     100.0        3.79
 6   HVY POLLUTING        267935.625    6.46    251677.250    1035.2      99.6        0.65
 7   LGT POLLUTING        168957.812    8.50    155727.875    1026.7      98.2        0.74
 8      COMMERCIAL         49680.977    8.33     45859.336     896.4      87.8        0.34
 9     AGRICULTURE         86541.000    2.01     84834.062     925.6      92.5        0.01
 10     HOME & REC        367354.750    6.01    346529.437    1167.6     100.0        2.62

                                 ** RESOURCE UTILIZATION DATA **

      RESOURCE            UTILIZATION          REMAINING   RECYCLE    THIS CYCLE
 NO.        NAME        USED IN YEAR   % USED STOCKPILE     RATIO     UNIT COST
  1             IRON        257.65     13.66    8633.71      0.0      0.00004976
  2           COPPER        190.00     28.11    9572.26      0.06     0.00006768
  3        LEAD,ZINC        333.44     28.31    9545.20      0.06     0.00001237
  4          MERCURY        516.49     69.63    3722.65      0.48     0.00000110
  5         . SILVER        319.69     77.41    2462.82      0.36     0.00000876
  6      TRACE METAL        237.54     10.16    8984.32      0.0      0.00000790
  7             COAL         52.49     52.93    4706.94      0.0      0.00088990
  8              OIL        513.30     28.98    7102.34      0.0      0.00011463
  9      ELECTRICITY       5317.79     53.18    4682.21      0.0      0.00004990
 10                           0.0       0.00       0.0       0.0      0.0
 11           LUMBER        549.09      0.00    9999.99      0.00     0.00016700
 12             FOOD       8953.25      0.00   10005.22      0.0      0.00033000
 13                           0.0       0.0    10000.00      0.0      0.0
 14       URBAN LAND       7337.89     73.38    2662.11      0.0      0.00001905
 15    SUBURBAN LAND       4361.86     43.62    5638.14      0.0      0.00001837
 16      ARABLE LAND       6479.09     43.19    8520.91      0.0      0.00001844
 17                           0.0       0.00       0.0       0.0      0.0
 18       WORK UNITS      79342.37     95.85    3432.13      0.0      0.00012439
 19        AIR UNITS       5120.00     51.20    4880.00      0.0      0.0
 20      WATER UNITS       5125.26     51.25    4874.74      0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT     PRESENT
 NUMBER     VALUE    RESILIENCE
   1        1.9942      0.1800
   2        0.5418      0.1130
   3        0.4392     -0.0978
   4        0.6050      0.1932
   5        5.3994      0.1216
   6        0.4812     -0.0116
   7        1.2455      0.0379
   8        0.4184     -0.1406
   9        0.4320      0.0739
  10        1.1182      0.0928
  11        0.5449      0.1194
  12        0.0         0.0

      ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**


 SHORT TERM FUNDS ADJUSTMENTS

 COMPONENT  MAINT.AMT    UNITS FROM
   NUMBER    DEFERRED    EXPORT BAL.
     2          855.50         0.0
     6         8038.07         0.0
     7         6758.31         0.0
     8         1987.24         0.0
 CUMULATIVE EXPORT BALANCE IS      169663.937

 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE       NEW VALUE
  NUMBER    UPGRADE  DEGRADE
    1        1.8528   0.0
    2        0.5036   0.0
    4        0.5673   0.0
    5        4.9460   0.0
   11        0.5336   0.0
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                                    YEAR IS     7

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  ****STATE OF THE SYSTEM****

                                        ** REGIONAL POPULATION **

AGE GROUP     POPULATION      EDUCATION     INSTITUTION      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL       216676.187
   <18         66414.562      49226.207        463.512       16601.988        122.856           0.0             0.0
  18-24        29561.086       9894.578        290.871           0.0          616.120       15846.785        2912.736
  25-65        97487.687          0.0          693.318           0.0          943.847       68671.500       27178.984
  >65          23212.777          0.0         1208.857           0.0        22003.930           0.0             0.0

                                 ** COMPONENT OPERATING DATA  **

      COMPONENT              OPERATING    MAINT.    PRODUCTION    OUTPUT     CAPITAL    ANNUAL %
  NO.        NAME          FUNDS(1000$)  COST(%)  FUNDS(1000$)              % USED    EXPANSION
  1       EDUCATION          98787.437     4.05     94946.375    1308.9      100.0        3.92
  2 TRANSPORTATION           17691.711    10.02     16080.285     972.5       94.2        0.46
  3          HEALTH          48408.422     9.12     44361.941    1389.2      100.0        4.81
  4   DEFENSE&OTHER         152810.125     3.82    147189.625    1104.7      100.0        1.43
  5         WELFARE         262219.687     5.86    247696.937    1341.1      100.0        4.28
  6   HVY POLLUTING         280528.562     6.77    262733.625    1075.2      100.0        1.04
  7   LGT POLLUTING         176725.750     8.54    162818.437    1065.8      100.0        0.91
  8      COMMERCIAL          50773.926     8.32     46872.129     913.2       89.5        0.30
  9     AGRICULTURE          86800.562     2.01     85088.500     926.3       92.6        0.01
  10     HOME & REC         381313.875     6.68    357449.812    1202.7      100.0        2.67

                               ** RESOURCE UTILIZATION DATA **

      RESOURCE              UTILIZATION         REMAINING   RECYCLE    THIS CYCLE
  NO.        NAME         USED IN YEAR   % USED STOCKPILE     RATIO    UNIT COST
  1          IRON             287.44     16.54     8346.28      0.0     0.00005013
  2        COPPER             171.55     26.90    10610.54      0.05    0.00006768
  3     LEAD,ZINC             346.71     30.76     9219.38      0.08    0.00001237
  4       MERCURY             471.26     70.82     3647.57      0.50    0.00000110
  5        SILVER             243.21     78.36     2380.85      0.37    0.00000887
  6   TRACE METAL             263.08     12.79     8721.23      0.0     0.00000790
  7          COAL              54.57     53.48     4652.37      0.0     0.00090808
  8           OIL             531.83     34.29     6570.51      0.0     0.00013246
  9   ELECTRICITY            5575.45     55.75     4424.55      0.0     0.00005321
  10                            0.0       0.00        0.0       0.0     0.0
  11       LUMBER             566.35      0.00     9999.99      0.00    0.00016700
  12         FOOD            9175.64      0.00    10005.22      0.0     0.00033000
  13                            0.0       0.0     10000.00      0.0     0.0
  14   URBAN LAND            7556.00     75.56     2444.00      0.0     0.00001911
  15 SUBURBAN LAND           4497.26     44.97     5502.74      0.0     0.00001839
  16  ARABLE LAND            6484.22     43.23     8515.78      0.0     0.00001844
  17                            0.0       0.00        0.0       0.0     0.0
  18   WORK UNITS           83088.94     98.31     1429.32      0.0     0.00014696
  19    AIR UNITS            5298.22     52.98     4701.78      0.0     0.0
  20  WATER UNITS            5244.48     52.44     4755.52      0.0     0.0

** SATISFACTION OF DEMANDS **
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   MEASURE     PRESENT       PRESENT
   NUMBER       VALUE      RESILIENCE
      1        2.0841        0.1248
      2        0.5687        0.1293
      3        0.4488       -0.0780
      4        0.6412        0.1301
      5        5.6620        0.1448
      6        0.4941        0.0149
      7        1.2666        0.0555
      8        0.4215       -0.1342
      9        0.4275        0.0628
     10        1.0960        0.0711
     11        0.5551        0.0402
     12        0.0           0.0
           ****ADJUSTMENTS  OF  SYSTEM****


 **RESOURCE ADJUSTMENTS**

   RESOURCE    SUBS.     STOCKPILE      YEAR
    NUMBER     NUMBER     INCREASE   COMPLETED
      8          7          0.0          9
      8        0.0        5000.         12

   SHORT TERM FUNDS ADJUSTMENTS

   COMPONENT  MAINT.AMT     UNITS FROM
    NUMBER     DEFERRED     EXPORT BAL.
      2          884.58          0.0
      8         2030.96          0.0
   CUMULATIVE EXPORT BALANCE IS         178695.125

   DEMAND THRESHOLD ADJUSTMENTS

   MEASURE        NEW VALUE
    NUMBER    UPGRADE  DEGRADE
      1        1.9942    0.0
      2        0.5418    0.0
      4        0.6050    0.0
      5        5.3994    0.0
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                                     YEAR IS     8

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  ****STATE OF THE SYSTEM****

                                              ** REGIONAL POPULATION **

     AGE GROUP     POPULATION      EDUCATION    INSTITUTION      PRESCHOOL      NON-WORKER      PAID WORKER  UNPAID WORKER

       TOTAL       219338.875
       <18          65942.437      45277.492        463.238      16077.820         123.893           0.0           0.0
       18-24        30286.246      10270.781        302.485          0.0           647.417       16126.867      2938.703
       25-65        99560.437          0.0          721.012          0.0           996.428       70290.937     27552.039
       >65          23549.750          0.0         1196.398          0.0         22353.352           0.0           0.0
                                           ** COMPONENT OPERATING DATA  **

       COMPONENT                OPERATING    MAINT.    PRODUCTION     OUTPUT      CAPITAL    ANNUAL %
   NO.         NAME           FUNDS(1000$)  COST(%)   FUNDS(1000$)               % USED     EXPANSION
   1       EDUCATION           106887.937     4.60    102186.375     1041.7        79.6        3.42
   2 TRANSPORTATION             18293.219    10.02     16627.930      743.8        72.0        0.40
   3          HEALTH            53200.805    10.32     48225.582     1141.2        82.1        4.20
   4   DEFENSE&OTHER           160450.500     4.49    153549.062      847.9        76.8        1.25
   5         WELFARE           285294.812     6.59    267663.187     1066.8        79.5        3.74
   6  HVY POLLUTING            293713.375     4.72    280463.625      879.6        81.8        0.91
   7  LGT POLLUTING            184859.187     5.07    175931.687      881.0        82.7        0.80
   8      COMMERCIAL            51890.918     8.32     47907.164      693.9        68.0        0.26
   9     AGRICULTURE            87060.875     2.01     85343.750      785.0        78.5        0.01
   10      HOME & REC          395803.437     7.29    368908.000     1240.0       100.0        2.73

                                          ** RESOURCE UTILIZATION DATA **

        RESOURCE            UTILIZATION           REMAINING    RECYCLE     THIS CYCLE
   NO.         NAME       USED IN YEAR   % USED  STOCKPILE      RATIO      UNIT COST
    1          IRON          241.72      18.95     8104.55       0.0       0.00005055
    2        COPPER          131.96      26.87    10969.97       0.05      0.00006768
    3     LEAD,ZINC          281.50      30.02    10157.93       0.07      0.00001237
    4       MERCURY          408.39      73.00     3375.59       0.53      0.00000110
    5        SILVER          198.36      79.67     2235.89       0.38      0.00000904
    6   TRACE METAL          223.61      15.02     8497.62       0.0       0.00000790
    7          COAL           49.80      53.97     4602.57       0.0       0.00092598
    8           OIL          353.37      36.08     6701.74       0.0       0.00014603
    9   ELECTRICITY         4581.51      45.82     5418.49       0.0       0.00005321
   10                          0.0        0.00        0.0        0.0       0.0
   11        LUMBER          538.83       0.00     9999.99       0.00      0.00016700
   12          FOOD         9191.86       0.00    10005.22       0.0       0.00033000
   13                          0.0        0.0     10000.00       0.0       0.0
   14    URBAN LAND         7215.95      72.16     2784.05       0.0       0.00001911
   15 SUBURBAN LAND         4255.23      42.55     5744.77       0.0       0.00001839
   16   ARABLE LAND         5495.27      36.64     9504.73       0.0       0.00001844
   17                          0.0        0.00        0.0        0.0       0.0
   18    WORK UNITS        65447.33      75.73    20970.42       0.0       0.00014696
   19     AIR UNITS         4486.77      44.87     5513.23       0.0       0.0
   20   WATER UNITS         4672.89      46.73     5327.11       0.0       0.0

 ** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1        1.6360      -0.1796
    2        0.4442      -0.1802
    3        0.3391      -0.3034
    4        0.5203      -0.1401
    5        4.4229      -0.1809
    6        0.4013      -0.1755
    7        1.0187      -0.1511
    8        0.3164      -0.3501
    9        0.3579      -0.1102
   10        0.9084      -0.1122
   11        0.5653       0.0594
   12        0.0          0.0
      ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT    UNITS FROM
    NUMBER    DEFERRED    EXPORT BAL.
      1       2137.76          0.0
      2        914.66          0.0
      3       1596.02          0.0
      5       8558.84          0.0
      6       8811.40          0.0
      7       7394.36          0.0
      8       2075.64         51.56
      9       1741.22          0.0
  CUMULATIVE EXPORT BALANCE IS        176875.812

  DEMAND THRESHOLD ADJUSTMENTS
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                              YEAR  IS     9

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    ****STATE  OF  THE  SYSTEM****

                                        ** REGIONAL POPULATION **

AGE GROUP    POPULATION      ECUCATION      INSTITUTION     PRESCHOCL      NCN-WCRKER    PAID WORKFR  UNPAID WORKER

  TCTAL      219954.687
   <18        64892.805      45180.684        434.804      19163.387        113.941        0.0           0.0
  18-24       30730.734      1CC50.328        303.762          0.0          638.348    15983.016      3755.291
  25-65      100713.125          0.0          697.768          0.0          927.935    65833.687     33253.727
   >65        23617.937          0.0         1193.779          0.0        22424.168        0.0           0.0

                                   ** CCMPONENT OPERATING DATA  **

     COMPONENT                  OPERATING   MAINT.   PRODUCTION    OUTPUT     CAPITAL    ANNUAL %
NO.        NAME               FUNDS(1000$)  COST(%)  FUNDS(1000$)              % USED    EXPANSION
1       FDUCATION              115652.687     6.25    108847.312    1276.8       97.5       3.04
2 TRANSPORTATION                18915.176    10.01     17194.191     884.6       85.6       0.36
3          HEALTH               58467.629    12.39     52023.395    1406.6      100.0       3.86
4   DEFENSE&OTHER              168472.875     4.24    161615.687    1028.5       93.1       1.11
5         WELFARE              31040C.562     9.05    284628.875    1307.3       97.5       3.32
6   HVY POLLUTING              307517.875     6.84    287819.875    1C23.0       95.1       0.81
7   LGT POLLUTING              193362.562     8.67    177928.562    1012.3       95.0       0.71
8      COMMERCIAL               53032.484     8.31     48965.016     814.3       79.8       0.23
9     AGRICULTURE               87321.937     4.01     83558.500     837.9       83.7       0.01
10     HOME & REC              410843.625     7.90    380771.187    1281.1      100.0       2.79

                                  ** PESOURCE UTI' IZATION DATA **

     RESOURCE                   UTILIZATICN            REMAINING   RECYCLE   THIS CYCLF
NO.        NAME               USED IN YEAR   % USED   STOCKPILE     RATIO    UNIT COST
 1             IRCN               279.68      21.75     7824.87      0.0     0.00005104
 2           COPPER               153.25      27.84    10824.55      0.06    0.00006768
 3        LEAD,ZINC               329.12      31.10    10335.54      0.08    0.00001237
 4          MERCURY               467.62      75.44     3070.52      0.57    0.00000110
 5           SILVER               238.78      81.25     2062.97      0.40    0.00000928
 6      TRACE METAL               260.54      17.63     8237.09      0.0     0.00000790
 7             COAL                62.57      54.60     4540.00      0.0     0.00094546
 8              OIL               304.33      30.70     9227.97      0.0     0.00014603
 9      ELECTRICITY              5394.18      53.94     4605.82      0.0     0.00005321
10                                  0.0        0.00        0.0       0.0     0.0
11           LUMBER               576.85       0.00     9959.99      0.00    C.00016700
12             FOOD              9539.62       0.00    10005.22      0.0     0.00033000
13                                  C.0        0.0     10000.00      0.0     0.0
14       URBAN LAND              7702.47      77.02     2297.53      0.0     0.00001911
15    SUBURBAN LAND              4568.29      45.68     5431.71      0.0     0.00001839
16      ARABLE LAND              5865.34      39.10     9134.66      0.0     0.00001844
17                                  0.0        0.00        0.0       0.0     0.0
18       WORK UNITS             7829C.75      95.69     3525.94      0.0     0.00014696
19        AIR UNITS              5096.32      50.96     49C3.68      0.0     0.0
20      WATER UNITS              5077.21      50.77     4922.79      0.0     0.0

** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1        2.1493       0.0778
    2        0.5397      -0.0039
    3        0.4022      -0.1739
    4        0.6395       0.0570
    5        5.4235       0.0045
    6        0.4627      -0.0496
    7        1.2438       0.0365
    8        0.3702      -0.2395
    9        0.3809      -0.0530
   10        1.0241       0.0009
   11        0.5824       0.0915
   12        0.0          0.0

      ****ADJUSTMENTS  OF  SYSTEM****


**RESCURCE ADJUSTMENTS**

 RESOURCE    SUBS.     STOCKPILE     YEAR
  NUMBER    NUMBER      INCREASE  CCMPLETED
    3         0.0        5000.         14
    4         0.0        2500.         14

 SHORT TERM FUNDS ADJUSTMENTS

 COMPONENT  MAINT.AMT     UNITS FROM
   NUMBER    DEFERRED     EXPORT BAL.
     1        2313.05          0.0
     2         945.76          0.0
     6        9225.53          0.C
     7        7734.50          0.0
     8        2121.30          0.0
     9        1746.44          0.0
 CUMULATIVE EXPORT BALANCE IS        176875.812

 DEMAND THRESHOLD ADJUSTMENTS
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                                   YEAR  IS     10

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   ****STATE  OF  THE  SYSTEM****


                                             ** REGICNAL POPULATION **

 AGE GROUP      POPULATION       ECUCATION     INSTITUTICN      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

   TCTAL        222415.812
    <18          64415.840       46990.816       453.008       16853.164        118.849          0.0            0.0
   18-24         31429.062       10663.219       323.774           0.0          682.051      16377.102       3382.933
   25-65        102779.500           0.0         755.272           0.0         1026.855      69971.562      31025.781
    >65          23791.301           0.0        1183.268           0.0        22608.035          0.0            0.0
                                  ** COMPONENT OPERATING DATA  **

      COMPONENT                 OPERATING    MAINT.    PRODUCTION     OUTPUT    CAPITAL    ANNUAL %
  NO.      NAME               FUNDS(1000$)  COST(%)   FUNDS(1000$)               % USED    EXPANSION
  1      EDUCATION             125136.125     6.07     117974.937    1384.1      100.0       3.30
  2 TRANSPORTATION              19558.277    10.00      17779.703     915.0       88.6       0.32
  3         HEALTH              64255.863     9.33      58773.992    1589.8      100.0       4.75
  4  DEFENSE&OTHER             176896.375     4.24     169702.375    1080.0       97.8       1.00
  5        WELFARE             337715.562     6.03     318508.000    1462.9      100.0       3.88
  6  HVY POLLUTING             321971.187     7.03     300836.937    1068.9       99.4       0.73
  7  LGT POLLUTING             202257.125     8.67     186114.812    1060.2       99.5       0.64
  8     COMMERCIAL              54199.164     8.30      50046.137     832.4       81.5       0.21
  9    AGRICULTURE              87583.812     4.01      84210.375     840.7       84.0       0.01
  10    HOME & REC             426455.312     8.53     392933.750    1322.1      100.0       2.83
                                 ** RESOURCE UTILIZATION DATA **

      RESOURCE              UTILIZATION          REMAINING    RECYCLE    THIS CYCLE
  NO.      NAME          USED IN YEAR   % USED  STOCKPILE      RATIO     UNIT COST
   1           IRON          291.41      24.67     7533.47      0.0      0.00005165
   2         COPPER          16C.21      28.85    10673.14      0.06     0.00006768
   3      LEAD,ZINC          346.57      32.20    10498.46      0.08     0.00001237
   4        MERCURY          500.51      76.50     2993.84      0.59     0.00000110
   5         SILVER          261.14      82.95     1875.91      0.41     0.00000954
   6    TRACE METAL          281.48      20.44     7955.61      0.0      0.00000790
   7           COAL           65.85      55.26     4474.15      0.0      0.00096796
   8            OIL          319.39      33.09     8908.59      0.0      0.00014603
   9    ELECTRICITY         5778.98      57.79     4221.02      0.0      0.00005497
  10                           0.0        0.00        0.0       0.0      0.0
  11         LUMBER          597.28       0.00     9999.99      0.00     0.00016700
  12           FOOD         9806.83       0.00    10005.22      0.0      0.00033000
  13                           0.0        0.0     10000.00      0.0      0.0
  14     URBAN LAND         7946.31      79.46     2053.69      0.0      0.00001922
  15 SUBURBAN LAND          4723.68      47.24     5276.32      0.0      0.00001843
  16    ARABLE LAND         5885.22      39.23     9114.78      0.0      C.00001844
  17                           0.0        0.00        0.0       0.0      0.0
  18     WORK UNITS        83344.81      96.52     3003.81      0.0      0.00014696
  19      AIR UNITS         5289.91      52.90     4710.09      0.0      0.0
  20    WATER UNITS         5222.33      52.22     4777.67      0.0      0.0

 ** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT    PRESENT
 NUMBER     VALUE    RESILIFNCE
   1       2.2150     0.1107
   2       0.5742     0.0598
   3       0.4114    -0.1549
   4       0.7148     0.1815
   5       5.9868     0.1088
   6       0.4786    -0.0168
   7       1.2328     0.0274
   8       0.3742    -0.2312
   9       0.3780    -0.0603
  10       0.9737    -0.0484
  11       0.5944     0.1140
  12       0.0        0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  SHORT TERM FUNCS ADJUSTMENTS

  COPPCNENT  MAINT.AMT    UNITS FROM
   NUMBER    DEFERRED    EXPORT BAL.
     2         977.91          0.C
     6        9659.13          0.C
     7        8090.28          0.0
     8        2167.97          0.C
     9        1751.68          0.0
  CUMULATIVE EXPORT BALANCE IS        176875.812

  DEMAND THRESHOLC ADJUSTMENTS

  MEASURE      NEW VALUE
   NUMBER   UPGRADE  DEGRADE
     1      2.1493    0.0
     4      0.6395    0.0
     5      5.4235    0.0
    11      0.5824    0.0
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                                    YEAR  IS    11

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****STATE  OF  THE  SYSTEM****

                                         ** REGIONAL POPULATION **

AGE GROUP      POPULATION        EDUCATION      INSTITUTION        PRESCHOOL       NON-WORKER      PAID WORKER  UNPAID WORKER

  TOTAL        224981.937
   <18          63998.582        47216.637          470.212        16187.965          123.781            0.0            0.0
  18-24         32155.613        11077.238          348.462              0.0          738.342      16614.293       3377.289
  25-65        104450.250              0.0          812.550              0.0         1116.649      71405.750      31115.270
   >65          24377.535              0.0         1172.923              0.0        23204.609            0.0            0.0

                              ** COMPONENT OPERATING DATA  **

     COMPONENT              OPERATING    MAINT.    PRODUCTION     OUTPUT     CAPITAL    ANNUAL %
   NO.       NAME          FUNDS(1000$)  COST(%)  FUNDS(1000$)               % USED    EXPANSION
   1      EDUCATION          135397.250    4.55    129500.875    1516.7      100.0        3.86
   2 TRANSPORTATION           20223.246   10.00     18385.129     945.9       91.6        0.29
   3         HEALTH           70617.125   11.35     63417.613    1704.6      100.0        4.97
   4  DEFENSE&OTHER          185741.000    4.28    178125.187    1132.9      100.0        1.14
   5        WELFARE          367434.250    6.78    344105.312    1579.2      100.0        4.24
   6  HVY POLLUTING          337103.750    7.40    313868.937    1110.4      100.0        0.56
   7  LGT POLLUTING          211560.812    8.77    194500.500    1104.2      100.0        0.91
   8     COMMERCIAL           55391.508    8.29     51150.988     849.2       83.2        0.19
   9    AGRICULTURE           87846.500    4.01     84462.937     842.4       84.2        0.00
  10     HOME & REC          442660.250    9.11    405692.812    1363.5      100.0        2.86

                              ** RESOURCE UTILIZATION DATA **

      RESOURCE              UTILIZATION          REMAINING   RECYCLE    THIS CYCLE
   NO.      NAME          USED IN YEAR   % USED STOCKPILE    RATIO     UNIT COST
    1           IRON            302.09    27.69    7231.37      0.0     0.00005237
    2         COPPER            166.47    29.89   10516.45      0.07    0.00006768
    3      LEAD,ZINC            361.02    29.04   12995.65      0.07    0.00001237
    4        MERCURY            524.49    71.19    4078.26      0.51    0.00000110
    5         SILVER            276.27    84.72    1680.36      0.43    0.00000983
    6    TRACE METAL            296.07    23.40    7659.54      0.0     0.00000790
    7           COAL             68.77    55.95    4405.37      0.0     0.00099183
    8            OIL            332.89    32.65    9775.94      0.0     0.00014603
    9    ELECTRICITY           6109.37    61.09    3890.63      0.0     0.00005957
   10                             0.0      0.00       0.0       0.0     0.0
   11         LUMBER            617.14     0.00    9999.99      0.00    0.00016700
   12           FOOD          10074.07     0.00   10005.22      0.0     0.00033000
   13                             0.0      0.0    10000.00      0.0     0.0
   14     URBAN LAND           8191.34    81.91    1808.66      0.0     0.00001930
   15  SUBURBAN LAND           4876.23    48.76    5123.77      0.0     0.00001846
   16    ARABLE LAND           5896.75    39.31    9103.25      0.0     0.00001844
   17                             0.0      0.00       0.0       0.0     0.0
   18     WORK UNITS          88031.81    99.90      88.02      0.0     0.00017259
   19      AIR UNITS           5476.06    54.76    4523.94      0.0     0.0
   20    WATER UNITS           5358.13    53.58    4641.87      0.0     0.0

** SATISFACTION OF DEMANDS **
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MEASURE   PRESENT     PRESENT
 NUMBER    VALUE    RESILIENCE
    1      2.3797      0.1072
    2      0.6166      0.1380
    3      0.4204     -0.1363
    4      0.7576      0.1848
    5      6.2706      0.1562
    6      0.4922      0.0111
    7      1.2580      0.0484
    8      0.3774     -0.2246
    9      0.3744     -0.0692
   10      0.9570     -0.0647
   11      0.6060      0.0405
   12      0.0         0.0

     ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE    SUBS.    STOCKPILE     YEAR
  NUMBER    NUMBER    INCREASE   COMPLETED
     9         8         0.0         21
    14        10         0.0         12

 SHORT TERM FUNDS ADJUSTMENTS

 COMPCNENT  MAINT.AMT    UNITS FRCM
  NUMBER     DEFERRED    EXPORT BAL
     2       1011.16          0.C
     8       2215.66          0.C
     9       1756.93          0.0
 CUMULATIVE EXPORT BALANCE IS        181569.500

 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
  NUMBER    UPGRADE  DEGRADE
     1       2.2150    0.0
     2       0.5742    0.0
     4       0.7148    0.0
     5       5.9868    0.0
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                                  YEAR IS    12

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     ****STATE CF THE SYSTEM****

                                          ** REGIONAL POPULATION **
AGE GROUP     POPULATION     EDUCATION     INSTITUTION      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL       227896.937
  <18          63697.289     47660.148        463.681      15449.809         123.657          0.0             0.0
  18-24        32310.812     11412.773        352.511          0.0           757.546      16478.687       3309.309
  25-65       106925.937         0.0          847.243          0.0          1185.114      73350.312      31543.242
  >65          24962.852         0.0         1169.452          0.0         23793.406          0.0             0.0
                                     ** COMPONENT OPERATING DATA  **

     COMPONENT             OPERATING     MAINT.    PRODUCTION      OUTPUT     CAPITAL    ANNUAL %
NO.        NAME          FUNDS(1000$)  COST(%)   FUNDS(1000$)                 % USED    EXPANSION
1       EDUCATION          146455.750     5.17     139292.500     1216.7       80.2        3.53
2  TRANSPORTATION           20910.824     9.99      19011.133      730.5       70.7        0.27
3          HEALTH           77608.125    12.08      69244.437     1411.9       82.8        4.54
4   DEFENSE&OTHER          195027.875     4.60     186456.625      880.8       77.8        1.04
5         WELFARE          399768.187     7.35     372410.312     1270.0       80.4        3.88
6   HVY POLLUTING          352947.562     5.25     335355.500      911.9       82.1        0.88
7   LGT PCLLUTING          221292.500     5.46     209834.187      914.6       82.8        0.83
8      COMMERCIAL           56610.082     8.28      52280.187      650.4       63.7        0.17
9     AGRICULTURE           88109.937     4.01      84716.312      709.5       70.9        0.00
10     HOME & REC          459480.937     9.65     419039.062     1409.3      100.0        2.90
                                     ** RESOURCE UTILIZATICN DATA **

     RESOURCE         UTILIZATION              REMAINING    RECYCLE    THIS CYCLE
NO.        NAME       USED IN YEAR    % USED   STOCKPILE      RATIO     UNIT COST
 1         IRON           247.73      30.16     6983.65       0.0      0.00005311
 2       COPPER           136.82      30.75    10388.22       0.07     0.00006768
 3    LEAD,ZINC           294.61      30.55    12719.66       0.07     0.00001237
 4      MERCURY           456.67      73.33     3775.21       0.54     0.00000110
 5       SILVER           227.15      86.17     1521.59       0.45     0.00001010
 6  TRACE METAL           253.17      25.94     7406.37       0.0      0.00000790
 7         COAL            60.95      56.56     4344.43       0.0      0.00101510
 8          OIL           278.35      33.45     9982.19       0.0      0.00014603
 9  ELECTRICITY          4943.26      49.43     5056.74       0.0      0.00005957
10                          0.0        0.00        0.0        0.0      0.0
11       LUMBER           592.49       0.00     9999.99       0.00     0.00016700
12         FOOD         10154.36       0.04    10001.47       0.0      0.00033000
13                          0.0        0.0     10000.00       0.0      0.0
14   URBAN LAND          7132.65      71.33     2867.35       0.0      0.00001930
15 SUBURBAN LAND         5061.41      50.61     4938.59       0.0      0.00001849
16  ARABLE LAND          4966.23      33.11    10033.77       0.0      0.00001844
17                          0.0        0.00        0.0        0.0      0.0
18   WORK UNITS         70004.25      77.93    19824.75       0.0      0.00017259
19    AIR UNITS          4693.96      46.94     5306.04       0.0      0.0
20  WATER UNITS          4804.96      48.05     5195.04       0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1       1.8737       -0.1541
    2       0.4857       -0.1541
    3       0.3205       -0.3416
    4       0.6196       -0.1333
    5       4.9112       -0.1797
    6       0.4007       -0.1768
    7       1.0166       -0.1528
    8       0.2854       -0.4137
    9       0.3113       -0.2261
   10       0.7898       -0.2281
   11       0.6184       ·0.0617
   12       0.0           0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.     STOCKPILE     YEAR
   NUMBER    NUMBER      INCREASE  COMPLETED
     2           2          0.0        22
     1         0.0       5000.         17
     2         0.0       5000.         17

  SHORT TERM FUNCS ADJUSTMENTS

  COMPONENT  MAINT.AMT     UNITS FROM
    NUMBER    DEFERRED     EXPORT BAL.
       1       2929.99          0.0
       2       1045.54          0.0
       3       2328.24          0.C
       5      11993.04          0.0
       6      10588.41          0.0
       7       8851.70          0.0
       8       2264.40         41.25
       9       1762.20          0.0
  CUMULATIVE EXPORT BALANCE IS        180C80.000

  DEMAND THRESHOLD ADJUSTMENTS
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                                     YEAR  IS    13

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     ****STATE  OF  THE  SYSTEM****

                                               ** REGICNAL POPULATION **

  AGE GROUP      POPULATION       ECUCATION    INSTITUTION      PRESCHOOL        NON-WORKER     PAID WORKER  UNPAID WORKER

    TOTAL        228746.937
     <18          64023.129       44725.930       446.448       18734.086          116.673          0.0            0.0
    18-24         31009.012       10569.332       335.654           0.0            708.064      15420.766       3975.207
    25-65        108446.250           0.0         817.390           0.0           1107.198      68648.562      37873.070
     >65          25268.551           0.0        1180.662           0.0          24087.891          0.0            0.0

                                    ** COMPONENT OPERATING DATA  **

       COMPONENT                OPERATING   MAINT.    PRODUCTION     OUTPUT     CAPITAL     ANNUAL %
   NO.      NAME              FUNDS(1000$)  COST(%)  FUNDS(1000$)               % USED     EXPANSION
   1      EDUCATION            158512.687     6.32    149094.437     1493.3      98.5        3.26
   2 TRANSPORTATION             21621.777     9.84     19685.594      866.2      83.9        0.25
   3         HEALTH             85251.250    12.93     75527.187     1757.1     100.0        4.43
   4   DEFENSE&OTHER           204779.062     3.81    197264.875     1069.9      94.4        0.96
   5        WELFARE            434947.500     9.15    398504.000     1560.1      98.8        3.58
   6  HVY POLLUTING            369536.062     6.63    346561.187     1065.8      96.0        0.81
   7  LGT PCLLUTING            231471.812     8.46    213417.375     1053.8      95.4        0.77
   8     COMMERCIAL             57855.465     7.91     53612.625      763.6      74.8        0.16
   9    AGRICULTURE             88374.187     3.99     84580.062      774.0      77.4        0.00
   10    HOME & REC            476940.812     9.69    434808.250     1464.0     100.0        2.98

                                   ** RESOURCE UTILIZATICN DATA **

       RESOURCE                UTILIZATICN            REMAINING    RECYCLE    THIS CYCLE
   NO.      NAME              USED IN YEAR   % USED  STOCKPILE      RATIO     UNIT CCST
    1             IRON            288.26     31.52     7179.98       0.0     0.00005366
    2           COPPER            157.56     30.73    10725.70       0.07    0.00006768
    3        LEAD,ZINC            35C.14     30.34    13594.10       0.07    0.00001237
    4          MERCURY            528.50     72.68     4031.65       0.53    0.00000110
    5           SILVER            276.25     87.90     1330.48       0.46    0.00001035
    6      TRACE METAL            303.62     28.97     7102.75       0.0     0.00000790
    7             COAL             79.30     57.35     4265.13       0.0     0.00104058
    8              OIL            322.16     35.60     9660.03       0.0     0.00014603
    9      ELECTRICITY           5572.64     55.73     4427.36       0.0     0.00005957
   10                               0.0       0.00        0.0        0.0     0.0
   11           LUMBER            635.44      0.00     9999.99       0.00    0.00016700
   12             FOOD          10607.90      0.00    10005.22       0.0     0.00033000
   13                               0.0       0.0     10000.00       0.0     0.0
   14       URBAN LAND           7613.91     76.14     2386.09       0.0     0.00001930
   15    SUBURBAN LAND           5436.30     54.36     4563.70       0.0     0.00001855
   16      ARABLE LAND           5418.27     36.12     9581.73       0.0     0.00001844
   17                               0.0       0.00        0.0        0.0     0.0
   18       WORK UNITS          84178.00     99.90       84.07       0.0     0.00017259
   19        AIR UNITS           5328.02     53.28     4671.98       0.0     0.0
   20      WATER UNITS           5264.68     52.65     4735.32       0.0     0.0

 ** SATISFACTION OF DEMANDS **
 MEASURE     PRESENT      PRESENT
  NUMBER      VALUE     RESILIENCE
     1        2.4445       0.1036
     2        0.5909       0.0292
     3        0.3787      -0.2221
     4        0.7682       0.0746
     5        5.9957       0.0015
     6        0.4633      -0.0482
     7        1.2606       0.0505
     8        0.3338      -0.3143
     9        0.3384      -0.1588
    10        0.9207      -0.1002
    11        0.6400       0.0988
    12        0.0          0.0
         ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**


  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT    UNITS FROM
    NUMBER    DEFERRED    EXPORT BAL.
       2       1081.09          0.0
       6      11086.07          0.0
       7       9258.87          0.0
       8       2314.22          1.58
       9       1767.48          0.0
  CUMULATIVE EXPORT BALANCE IS       179941.375

  DEMAND THRESHOLD ADJUSTMENTS
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                                  YEAR IS     14

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     ****STATE  OF  THE  SYSTEM****

                                   ** REGIONAL POPULATION **

AGE GROUP      POPULATION      EDLCATION     INSTITUTION      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL        231710.687
  <18           64970.645      47487.352        478.787      16880.199         124.311          0.0            0.0
  18-24         29991.129      10589.051        340.461          0.0           714.400      14956.590       3390.632
  25-65        110966.375          0.0          900.402          0.0          1227.934      73323.500      35514.527
  >65           25782.512          0.0         1193.160          0.0         24589.355          0.0            0.0
                                ** CCMPONENT OPEPATING DATA  **

        COMPONENT             OPERATING    MAINT.    PRODUCTION     OUTPUT     CAPITAL     ANNUAL %
   NO.       NAME           FUNDS(1000$)  COST(%)   FUNDS(1000$)              % USED     EXPANSION
   1       EDUCATION         171510.687     4.28    164469.062     1648.5      100.0         3.63
   2 TRANSPORTATION           22356.902     9.84     20354.891      895.6       86.7         0.23
   3          HEALTH          93735.000    10.11     85128.187     1985.8      100.0         5.02
   4   DEFENSE&OTHER         215017.812     3.90    206944.312     1122.7       99.1         0.90
   5         WELFARE         473222.562     6.11    445957.937     1746.6      100.0         4.06
   6   HVY POLLUTING         386904.187     7.21    360876.125     1110.3      100.0         0.75
   7   LGT POLLUTING         242119.375     8.58    222977.000     1102.2       99.8         0.71
   8      COMMERCIAL          59128.246     7.91     54792.066      780.9       76.5         0.15
   9     AGRICULTURE          88639.187     3.99     85234.875      776.7       77.6         0.00
  10      HOME & REC         495064.125     9.97    450169.312     1516.0      100.0         3.02
                              ** RESOURCE UTILIZATION DATA **

         RESOURCE            UTILIZATION            REMAINING    RECYCLE     THIS CYCLE
   NO.        NAME          USED IN YEAR   % USED  STOCKPILE     RATIO       UNIT COST
   1          IRON              299.69     27.07     9710.85       0.0       0.00005366
   2        COPPER              159.97     26.80    13406.86       0.05      0.00006768
   3     LEAD,ZINC              374.78     31.35    13729.63       0.08      0.00001237
   4       MERCURY              567.64     73.98     3902.53       0.55      0.00000110
   5        SILVER              303.02     89.79     1123.44       0.48      0.00001064
   6   TRACE METAL              339.63     32.37     6763.12       0.0       0.00000790
   7          COAL               97.11     58.32     4168.02       0.0       0.00107309
   8           OIL              339.94     37.87     9320.09       0.0       0.00015258
   9   ELECTRICITY             5557.88     55.58     4442.12       0.0       0.00005957
  10                              0.0       0.00        0.0        0.0       0.0
  11        LUMBER              659.16      0.00     9999.99       0.00      0.00016700
  12          FOOD            10944.81      0.00    10005.22       0.0       0.00033000
  13                              0.0       0.0     10000.00       0.0       0.0
  14    URBAN LAND             7875.80     78.76     2124.20       0.0       0.00001930
  15 SUBURBAN LAND             5631.46     56.31     4368.54       0.0       0.00001861
  16   ARABLE LAND             5436.55     36.24     9563.45       0.0       0.00001844
  17                              0.0       0.00        0.0        0.0       0.0
  18    WORK UNITS            90235.75     99.90       88.28       0.0       0.00017259
  19     AIR UNITS             5527.77     55.28     4472.23       0.0       0.0
  20   WATER UNITS             5422.87     54.23     4577.13       0.0       0.0

** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1       2.5486       0.1506
    2       0.6388       0.1125
    3       0.3865      -0.2060
    4       0.8570       0.1989
    5       6.5523       0.0945
    6       0.4774      -0.0192
    7       1.2531       0.0443
    8       0.3370      -0.3077
    9       0.3352      -0.1667
   10       0.8798      -0.1402
   11       0.6542       0.1233
   12       0.0          0.0

       ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE     SUBS.     STOCKPILE       YEAR
  NUMBER     NUMBER      INCREASE    COMPLETED
     3         0.0        5000.          19
     6         0.0       10000.          19

 SHORT TERM FUNDS ADJUSTMENTS

 COMPONENT   MAINT.AMT      UNITS FROM
  NUMBER     DEFERRED      EXPORT BAL.
     2        1117.84           0.0
     6       11607.12           0.0
     7        9684.77           0.0
     8        2365.13           0.95
     9        1772.78           0.0
CUMULATIVE EXPORT BALANCE IS          179875.000

DEMAND THRESHOLD ADJUSTMENTS

MEASURE        NEW VALUE
 NUMBER     UPGRADE  DEGRADE
    1       2.4445    0.0
    2       0.5909    0.0
    4       0.7682    0.0
   11       0.6400    0.0
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                                      YEAR  IS    15

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     ****STATE  CF  THE  SYSTEM****

                                                   ** REGIONAL POPULATION **

  AGE GROUP       POPULATION        EDLCATION       INSTITUTICN        PRESCHOOL        NON-WORKER     PAID WORKER  UNPAID WORKER

     TOTAL       234712.812
      <18         65965.125        48943.078         502.114         16389.449          130.490           0.0            0.0
     18-24        28963.172        1C478.655         344.140             0.0            724.220       14238.051       3178.077
     25-65       113518.812            0.0           976.966             0.0           1341.247       75327.187      35873.367
      >65         26265.398            0.0          1183.172             0.0          25082.227           0.0            0.0

                                       ** COMPONENT OPERATING DATA  **

       COMPONENT               OPERATING     MAINT.     PRODUCTION     OUTPUT     CAPITAL     ANNUAL %
    NO.        NAME           FUNDS(1000$)  COST(%)    FUNDS(1000$)               % USED     EXPANSION
    1       EDUCATION          185574.500     4.75      177163.500     1777.0      100.0        3.91
    2 TRANSPORTATION            23117.023     9.84       21C46.941      925.6       89.6        0.22
    3          HEALTH          103014.625    11.69       92233.187     2157.3      100.0        5.26
    4   DEFENSE&OTHER          225768.500     3.95      217184.062     1178.8      100.0        1.10
    5         WELFARE          514865.812     6.84      481915.875     1868.4      100.0        4.33
    6   HVY POLLUTING          405088.625     7.56      376630.875     1159.1      100.0        0.99
    7   LGT POLLUTING          253256.750     8.68      233C23.062     1152.0      100.0        0.95
    8      COMMERCIAL           60429.027     7.91       55997.457      798.6       78.2        0.14
    9     AGRICULTURE           88905.000     3.99       85490.500      779.0       77.9        0.00
    10     HOME & REC          513876.125    10.09      466772.250     1572.0      100.0        3.06

                                     ** RESCURCE UTILIZATION DATA **

       RESOURCE               UTILIZATION            REMAINING    RFCYCLE    THIS CYCLE
    NO.        NAME         USED IN YEAR    % USED  STOCKPILE     RATIO     UNIT COST
     1          IRON            312.08      29.41     9398.77      0.0      0.00005366
     2        COPPER            155.99      27.63    13255.06      0.06     0.00006768
     3     LEAD,ZINC            402.56      32.43    13841.02      0.08     0.00001237
     4       MERCURY            600.69      76.57     3514.32      0.59     0.00000110
     5        SILVER            324.43      91.77      904.78      0.51     C.00002011
     6   TRACE METAL            378.49      32.96     7353.83      0.0      0.00000790
     7          COAL            121.18      59.53     4046.83      0.0      0.00111401
     8           OIL            355.79      40.24     8964.30      0.0      0.00016290
     9   ELECTRICITY           5233.05      52.33     4766.95      0.0      0.00005957
    10                            0.0        0.00         0.0      0.0      0.0
    11        LUMBER            684.35       0.00     9999.99      0.00     C.00016700
    12          FOOD          11307.52       1.62     9843.48      0.0      0.00033000
    13                            0.0        0.0     10000.00      0.0      0.0
    14    URBAN LAND           8155.47      81.55     1844.53      0.0      0.00001930
    15 SUBURBAN LAND           5840.15      58.40     4159.85      0.0      0.00001866
    16   ARABLE LANC           5453.12      36.35     9546.88      0.0      C.00001844
    17                            0.0        0.00         0.0      0.0      0.0
    18    WORK UNITS          95407.56      99.90       89.57      0.0      0.00017259
    19     AIR UNITS           5741.54      57.42     4258.46      0.0      0.0
    20   WATER UNITS           5590.17      55.90     4409.83      0.0      0.0

  ** SATISFACTION OF DEMANDS **
  MEASURE    PRESENT     PRESENT
  NUMBER      VALUE     RESILIENCE
     1        2.6711      0.0927
     2        0.6762      0.1444
     3        0.3944     -0.1899
     4        0.9191      0.1965
     5        6.9227      0.1563
     6        0.4923      0.0114
     7        1.2902      0.0752
     8        0.3403     -0.3010
     9        0.3319     -0.1749
    10        0.8698     -0.1499
    11        0.6698      0.0465
    12        0.0         0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.    STOCKPILE     YEAR
   NUMBER    NUMBER     INCREASE  COMPLETED
     14        10          0.0        16
      4        0.0       2500.        20

  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT    UNITS FROM
   NUMBER    DEFERRED    EXPORT BAL.
      2       1155.85         0.0
      8       2417.16         0.0
      9       1778.10         0.0
  CUMULATIVE EXPORT BALANCE IS      185654.125

  DEMAND THRESHOLD ADJUSTMENTS

  MEASURE       NEW VALUE
   NUMBER    UPGRADE  DEGRADE
      2       0.6388   0.0
      4       0.8570   0.0
      5       6.5523   0.0
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                                    YEAR IS    16

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     ****STATE  CF  THE  SYSTEM****

                                                      ** REGIONAL POPULATION **

  AGE GROUP     POPULATION      EDUCATION    INSTITUTION      PRESCHCOL      NON-WORKER    PAID WORKER  UNPAID WORKER

    TOTAL       237753.875
     <18         67007.250      50154.484        516.969      16201.309         134.491           0.0            0.0
    18-24        27924.961      10248.508        339.076            0.0         715.101     13613.680       3008.603
    25-65       116102.875            0.0       1028.364            0.0        1419.028     77260.687      36394.738
     >65         26718.777            0.0       1184.358            0.0       25534.426           0.0            0.0
                                   ** COMPONENT OPERATING DATA  **

        COMPONENT              OPERATING   MAINT.    PRODUCTION    OUTPUT    CAPITAL   ANNUAL %
     NO.       NAME         FUNDS(1000$)  COST(%)  FUNDS(1000$)              % USED   EXPANSION
     1       EDUCATION        200791.562     4.97    191286.125    1920.2     100.0      4.16
     2 TRANSPORTATION          23902.988     9.84     21762.527     957.2      92.7      0.20
     3          HEALTH        113212.937    11.42    101607.750    2375.0     100.0      5.56
     4   DEFENSE&OTHER        237056.750     4.39    227087.875    1233.1     100.0      1.32
     5         WELFARE        560173.625     7.10    523047.625    2050.7     100.0      4.59
     6   HVY POLLUTING        424127.750     5.50    402026.125    1233.9     100.0      1.32
     7   LGT POLLUTING        264906.437     5.40    251329.375    1242.6     100.0      1.37
     8      COMMERCIAL         61758.426     7.91     57229.363     816.9      80.0      0.13
     9     AGRICULTURE         89171.625     3.99     85746.875     781.4      78.1      0.00
     10     HOME & REC        533402.937    10.28    483697.937    1632.1     100.0      3.11
                                   ** RESOURCE UTILIZATION DATA **

         RESOURCE            UTILIZATION          REMAINING   RECYCLE    THIS CYCLE
     NO.      NAME         USED IN YEAR  % USED  STOCKPILE     RATIO     UNIT COST
      1           IRON          331.16    29.26   10267.86     0.0      0.00005366
      2         COPPER          160.25    26.71   14303.73     0.05     0.00006768
      3      LEAD,ZINC          442.61    30.25   16263.32     0.07     0.00001237
      4        MERCURY          644.94    78.02    3350.06     0.61     0.00000110
      5         SILVER          352.55    93.90     670.58     0.53     0.00005091
      6    TRACE METAL          433.31    24.35   12581.64     0.0      0.00000790
      7           COAL          152.93    61.06    3893.91     0.0      0.00116650
      8            OIL          376.39    42.75    8587.91     0.0      0.00017445
      9    ELECTRICITY         4763.57    47.64    5236.43     0.0      0.00005957
     10                            0.0     0.00        0.0     0.0      0.0
     11         LUMBER          716.86     0.00    9999.99     0.00     0.00016700
     12           FOOD        11695.66     6.78    9327.08     0.0      0.00033000
     13                            0.0     0.0    10000.00     0.0      0.0
     14     URBAN LAND         7608.31    76.08    2391.69     0.0      0.00001930
     15  SUBURBAN LAND         6509.63    65.10    3490.37     0.0      0.00001876
     16    ARABLE LAND         5469.50    36.46    9530.50     0.0      0.00001844
     17                            0.0     0.00        0.0     0.0      0.0
     18     WORK UNITS       101289.44    99.90      90.88     0.0      0.00017259
     19      AIR UNITS         6014.39    60.14    3985.61     0.0      0.0
     20    WATER UNITS         5829.59    58.30    4170.41     0.0      0.0

  ** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT      PRESENT
 NUMBER     VALUE     RESILIENCE
    1       2.8246      0.1555
    2       0.7176      0.1234
    3       0.4026     -0.1729
    4       0.9989      0.1656
    5       7.3758      0.1257
    6       0.5208      0.0699
    7       1.3626      0.1355
    8       0.3436     -0.2942
    9       0.3286     -0.1830
   10       0.8598     -0.1597
   11       0.6865      0.0726
   12       0.0         0.0

      ****ADJUSTPENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.    STOCKPILE     YEAR
   NUMBER    NUPBER     INCREASE  COMPLFTFD
      5        0.0        1000.        21
      7        0.0        5000.        21

  SHORT TERM FUNCS ADJUSTMENTS

  COMPCNENT  MAINT.APT    UNITS FRCM
   NUMBER     DEFERRED    EXPORT EAL.
      2       1195.15          0.C
      8       2470.34          0.C
      9       1783.43          0.12
  CUMULATIVE EXPORT BALANCE IS       223745.687

  DEPAND THRESHCLD ADJUSTPENTS

  MEASURE        NEW VALUE
   NUMBER    UPGRADE  CEGRADE
      1       2.6711    0.0
      2       0.6762    0.0
      4       0.9191    0.0
      5       6.9227    0.0
      7       1.2902    0.0
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                                    YEAR IS   17

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   ****STATE  OF  THE  SYSTEM****


                                              ** REGICNAL POPULATION **

AGE GROUP     POPULATICN      ECUCATION      INSTITUTICN      PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TCTAL       240834.312
   <18         68099.562      51419.590         537.891       16003.129
  18-24        26873.727       5553.125         335.035           0.0          138.955          0.0            0.0
  25-65       118716.937          0.0          1086.464           0.0          702.538      13058.371       2824.662
   >65         27143.887          0.0          1190.003           0.0         1494.703      79493.250      36642.500
                                                                              25953.891          0.0            0.0
                                        ** COMPONENT OPERATING DATA  **

         COMPONENT                OPERATING    MAINT.     PRODUCTION      OUTPUT      CAPITAL     ANNUAL %
   NO.        NAME              FUNDS(1000$)   COST(%)    FUNDS(1000$)                % USED     EXPANSION
   1        EDUCATION             217256.375     4.88      207144.437     2080.4      100.0        4.40
   2 TRANSPORTATION                24715.676     9.84       22502.441      989.3       95.8        0.19
   3           HEALTH             124420.875    11.67      111418.875     2618.3      100.0        5.83
   4   DEFENSE&OTHER              248909.375     4.81      237481.812     1250.0      100.0        1.51
   5          WELFARE             609468.500     6.94      565916.375     2235.5      100.0        4.85
   6   HVY POLLUTING              444061.687     6.64      416395.687     1280.2      100.0        1.46
   7   LGT POLLUTING              277092.000     6.36      260511.375     1287.4      100.0        1.50
   8       COMMERCIAL              63117.070     7.91       58488.371      836.9       82.0        0.12
   9      AGRICULTURE              89439.062     3.59       86004.062      783.6       78.3        0.00
   10      HOME & REC             553671.750    10.47      501183.875     1692.2      100.0        3.14
                                        ** RESOURCE UTILIZATION DATA **

          RESOURCE             UTILIZATICN              REMAINING     RECYCLE     THIS CYCLE
   NO.          NAME          USED IN YEAR    % USED   STOCKPILE      RATIO       UNIT COST
    1           IRON              342.91      30.60     10409.55       0.0        0.00005366
    2         COPPER              153.71      26.79     14642.42       0.05       0.00006768
    3      LEAD,ZINC              480.67      32.17     15815.43       0.08       0.00001237
    4        MERCURY              686.33      73.95      4338.71       0.55       0.00000110
    5         SILVER              380.99      95.33       518.34       0.55       0.00011541
    6    TRACE METAL              493.78      27.31     12087.86       0.0        0.00000790
    7           COAL              194.47      60.09      4184.04       0.0        0.00117728
    8            OIL              394.97      45.38      8192.94       0.0        0.00018737
    9    ELECTRICITY             3946.40      39.46      6053.60       0.0        0.00005957
   10                                0.0       0.00          0.0       0.0        0.0
   11         LUMBER              742.61       0.00      9999.99       0.00       0.00016700
   12           FOOD            12083.79      15.50      8454.59       0.0        0.00033000
   13                                0.0       0.0      10000.00       0.0        0.0
   14     URBAN LAND             7878.39      78.78      2121.61       0.0        0.00001930
   15  SUBURBAN LAND             6742.77      67.43      3257.23       0.0        0.00001888
   16    ARABLE LAND             5485.18      36.57      9514.82       0.0        0.00001844
   17                                0.0       0.00          0.0       0.0        0.0
   18     WORK UNITS           107540.06      99.90        92.56       0.0        0.00017259
   19      AIR UNITS             6231.17      62.31      3768.83       0.0        0.0
   20    WATER UNITS             5993.84      59.94      4006.16       0.0        0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT      PRESENT
 NUMBER     VALUE     RESILIENCE
    1      2.9968       0.1219
    2      0.7637       0.1293
    3      0.4108      -0.1562
    4      1.0872       0.1829
    5      7.9019       0.1414
    6      0.5331       0.0950
    7      1.3871       0.0751
    8      0.3475      -0.2861
    9      0.3254      -0.1911
   10      0.8467      -0.1725
   11      0.7026       0.0979
   12      0.0          0.0

       ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE    SUBS.    STOCKPILE     YEAR
  NUMBER    NUMBER     INCREASE  COMPLETED
    1         0.0       5000.        22

 SHORT TERM FUNDS ADJUSTMENTS

 COMPONENT  MAINT.AMT    UNITS FRCM
  NUMBER     DEFERRED    EXPORT BAL.
     2       1235.78          0.0
     8       2524.68          0.0
     9       1788.78          1.16
 CUMULATIVE EXPORT BALANCE IS     266075.687

 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
  NUMBER    UPGRADE  DEGRADE
     1      2.8246    0.0
     2      0.7176    0.0
     4      0.9989    0.0
     5      7.3758    0.0
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                                    YEAR IS    18

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****STATE  OF  THE  SYSTEM****

                                        ** REGIONAL POPULATION **

AGE GROUP     POPULATION      EDUCATION    INSTITUTION     PRESCHOOL     NON-WORKER    PAID WORKER  UNPAID WORKER

  TOTAL       243954.687
   <18         69038.375      52622.836       558.125      15713.953        143.456         0.0            0.0
  18-24        26013.820       9805.477       335.481          0.0          700.772     12493.375       2678.728
  25-65       121360.187          0.0        1160.322          0.0         1594.267     81440.562      37164.984
   >65         27542.160          0.0        1192.895          0.0        26349.273         0.0            0.0
                                 ** COMPONENT OPERATING DATA  **

      COMPONENT              OPERATING    MAINT.    PRODUCTION     OUTPUT    CAPITAL    ANNUAL %
   NO.      NAME           FUNDS(1000$)  COST(%)   FUNDS(1000$)              % USED    EXPANSION
    1      EDUCATION         235071.312    4.95     223975.812     2251.9     100.0       4.61
    2 TRANSPORTATION          25555.592    9.84      23267.508     1022.6      99.0       0.18
    3         HEALTH         136738.375   11.99     122100.312     2881.0     100.0       6.05
    4  DEFENSE&OTHER         261354.625    4.87     249223.750     1354.4     100.0       1.70
    5        WELFARE         663101.312    7.05     619454.875     2431.2     100.0       5.06
    6  HVY POLLUTING         464932.500    6.95     434708.625     1340.5     100.0       1.64
    7  LGT POLLUTING         289838.062    6.58     271941.250     1345.2     100.0       1.66
    8     COMMERCIAL          64505.602    7.91      59775.074      855.9      83.8       0.11
    9    AGRICULTURE          89707.312    3.99      86262.000      786.2      78.6       0.00
   10     HOME & REC         574710.750   10.65     519400.687     1753.9     100.0       3.17
                                 ** RESOURCE UTILIZATION DATA **

      RESOURCE             UTILIZATION           REMAINING   RECYCLE    THIS CYCLE
   NO.      NAME          USED IN YEAR   % USED  STOCKPILE    RATIO     UNIT COST
    1          IRON            358.02    31.96    10536.12     0.0      0.00005380
    2        COPPER            147.80    27.49    14502.17     0.06     0.00006768
    3     LEAD,ZINC            524.29    32.57    16531.47     0.08     0.00001240
    4       MERCURY            732.34    76.80     3865.30     0.59     0.00000110
    5        SILVER            412.46    92.99      817.54     0.52     0.00003306
    6   TRACE METAL            560.55    26.81    13927.80     0.0      0.00000790
    7          COAL            228.27    49.03     6786.33     0.0      0.00117728
    8           OIL            415.56    48.15     7777.38     0.0      0.00020179
    9   ELECTRICITY           3461.25    34.61     6538.75     0.0      0.00005957
   10                            0.0      0.00        0.0      0.0      0.0
   11        LUMBER            770.76     0.00     9999.99     0.00     0.00016700
   12          FOOD          12483.11    27.83     7220.34     0.0      0.00033000
   13                            0.0      0.0     10000.00     0.0      0.0
   14    URBAN LAND           8155.51    81.56     1844.49     0.0      0.00001930
   15 SUBURBAN LAND           6991.63    69.92     3008.37     0.0      0.00001894
   16   ARABLE LAND           5503.55    36.69     9496.45     0.0      0.00001844
   17                            0.0      0.00        0.0      0.0      0.0
   18    WORK UNITS         114282.06    99.90       93.94     0.0      0.00017259
   19     AIR UNITS           6480.06    64.80     3519.94     0.0      0.0
   20   WATER UNITS           6185.89    61.86     3814.11     0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT     PRESENT
 NUMBER     VALUE     RESILIFNCE
    1       3.1733      0.1235
    2       0.8121      0.1316
    3       0.4192     -0.1389
    4       1.1810      0.1822
    5       8.4453      0.1450
    6       0.5504      0.1308
    7       1.4296      0.1080
    8       0.3509     -0.2792
    9       0.3223     -0.1988
   10       0.8370     -0.1820
   11       0.7190      0.1234
   12       0.0         0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

 RESOURCE    SUBS.    STOCKPILE     YEAR
  NUMBER    NUMBER     INCREASE   COMPLETED
    14        10         0.0         19

 SHCRT TERM FUNCS ADJUSTMENTS

 COMPONENT  MAINT.AMT    UNITS FRCM
  NUMBER    DEFERRED     EXPORT BAL.
    2        1277.80         0.0
    8        2580.22         0.C
    9        1794.15         2.29
 CUMULATIVE EXPORT BALANCE IS       329552.187

 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
  NUMBER    UPGRADE  DEGRADE
    1       2.9968    0.0
    2       0.7637    0.0
    4       1.0872    0.0
    5       7.9019    0.0
    6       0.5331    0.0
    7       1.3871    0.0
   11       0.7026    0.0
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                                    YEAR IS    19

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   ****STATE  OF  THE  SYSTEM****


                                              ** REGIONAL  POPULATION **

AGE GROUP     POPULATION     EDUCATION    INSTITUTION     PRESCHOOL      NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL       247115.500
   <18         69988.437     53830.191       578.501      15431.922        147.825          0.0            0.0
  18-24        25159.195      9624.039       334.449          0.0          695.324      11973.430       2531.954
  25-65       124053.437         0.0        1234.199          0.0         1691.189      83563.937      37564.082
   >65         27914.375         0.0        1196.278          0.0        26718.102          0.0            0.0

                                  ** COMPONENT OPERATING DATA  **

       COMPONENT                 OPERATING    MAINT.     PRODUCTION      OUTPUT      CAPITAL     ANNUAL %
   NO.        NAME             FUNDS (1000$)  COST(%)   FUNDS(1000$)                 % USED     EXPANSION
    1       EDUCATION            254347.062     5.34     241461.062      2429.2       100.0        4.78
    2 TRANSPORTATION              26424.879     9.84      24058.586      1057.5       100.0        0.29
    3          HEALTH            150275.312    12.93     133073.187      3146.8       100.0        6.22
    4   DEFENSE&OTHER            274422.125     5.34     260502.812      1416.2       100.0        1.85
    5         WELFARE            721453.750     7.53     670915.687      2634.3       100.0        5.23
    6  HVY POLLUTING             486784.250     7.72     451900.125      1395.2       100.0        1.77
    7  LGT POLLUTING             303170.437     7.07     283140.312      1400.7       100.0        1.79
    8      COMMERCIAL             65924.625     7.91      61090.035       875.3        85.7        0.11
    9     AGRICULTURE             89976.312     3.99      86520.625       788.6        78.8        0.00
   10      HOME & REC            596545.250    10.80     538392.187      1821.0       100.0        3.20

                                  ** RESOURCE UTILIZATION DATA **

       RESOURCE               UTILIZATION              REMAINING    RECYCLE    THIS CYCLE
   NO.        NAME           USED IN YEAR    % USED    STOCKPILE     RATIO     UNIT COST
    1            IRON             371.92      29.05     12994.77      0.0      0.00005380
    2          COPPER             142.21      28.16     14367.59      0.06     0.00006768
    3       LEAD,ZINC             565.47      34.02     16494.83      0.09     0.00001260
    4         MERCURY             778.50      76.96      3975.72      0.59     0.00000110
    5          SILVER             443.80      95.50       525.34      0.55     0.00012899
    6     TRACE METAL             624.67      28.64     14272.33      0.0      0.00000790
    7            COAL             258.79      50.98      6527.55      0.0      0.00117728
    8             OIL             436.35      51.06      7341.03      0.0      0.00021787
    9     ELECTRICITY            3097.84      30.98      6902.16      0.0      0.00005957
   10                               0.0       0.00          0.0      0.0      0.0
   11          LUMBER             800.16       0.12      9988.41      0.00     0.00016700
   12            FOOD           12916.00      44.16      5586.98      0.0      0.00033000
   13                               0.0        0.0      10000.00      0.0      0.0
   14     URBAN LAND             7608.73      76.09      2391.27      0.0      0.00001930
   15  SUBURBAN LAND             7676.08      76.76      2323.92      0.0      0.00001908
   16    ARABLE LAND             5520.08      36.80      9479.92      0.0      0.00001844
   17                               0.0       0.00          0.0      0.0      0.0
   18     WORK UNITS           121144.37      99.90        95.54      0.0      0.00017259
   19      AIR UNITS             6726.40      67.26      3273.60      0.0      0.0
   20    WATER UNITS             6377.63      63.78      3622.37      0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE    PRESENT     PRESENT
 NUMBER     VALUE    RESILIENCE
     1      3.3532      0.1189
     2      0.8610      0.1275
     3      0.4280     -0.1209
     4      1.2734      0.1713
     5      9.0053      0.1396
     6      0.5657      0.0612
     7      1.4632      0.0549
     8      0.3542     -0.2723
     9      0.3191     -0.2067
    10      0.8254     -0.1933
    11      0.7369      0.0488
    12      0.0         0.0
         ****ADJUSTMENTS  OF  SYSTEM****

  **RESOURCE ADJUSTMENTS**

    SHORT TERM FUNDS ADJUSTMENTS

    COMPONENT  MAINT.AMT    UNITS FROM
      NUMBER    DEFERRED    EXPORT BAL.
        2       1321.24         0.0
        8       2636.98         0.0
        9       1799.53         3.81
    CUMULATIVE EXPORT BALANCE IS        362805.187

    DEMAND THRESHOLD ADJUSTMENTS

    MEASURE      NEW VALUE
     NUMBER   UPGRADE  DEGRADE
       1      3.1733    0.0
       2      0.8121    0.0
       4      1.1810    0.0
       5      8.4453    0.0
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                                    YEAR IS    20
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    ****STATE OF THE SYSTEM****

                                         ** REGICNAL POPULATION **

 AGE GROUP     POPULATION       ECUCATION      INSTITUTION      PRESCHOOL      NON-WORKER      PAID WORKER  UNPAID WORKER

   TCTAL       250317.250
   <18          70951.125       54994.113        596.844        15208.125         152.036          0.0            0.0
   18-24        25537.695        5911.633        348.622            0.0           723.224      12031.910       2522.319
   25-65       125562.437           0.0         1294.657            0.0          1773.343      84760.937      37733.445
   >65          28265.840           0.0         1198.105            0.0         27067.738          0.0            0.0
                                      ** COMPONENT OPERATING DATA  **

        COMPONENT              OPERATING   MAINT.   PRODUCTION    OUTPUT     CAPITAL    ANNUAL %
     NO.        NAME         FUNDS(1000$) COST(%) FUNDS(1000$)               % USED    EXPANSION
     1        EDUCATION       275203.437    5.66   260452.250    2620.8      100.0        4.94
     2 TRANSPORTATION          27323.309    9.93    24856.082    1092.1      100.0        0.44
     3           HEALTH       165152.375   13.54   145461.187    3442.5      100.0        6.38
     4   DEFENSE&OTHER        288143.000    5.75   272476.375    1481.5      100.0        1.98
     5          WELFARE       784941.187    7.94   727186.562    2855.9      100.0        5.39
     6   HVY POLLUTING        509663.062    8.34   470414.812    1452.4      100.0        1.88
     7   LGT POLLUTING        317116.125    7.50   294996.187    1457.8      100.0        1.90
     8      COMMERCIAL         67374.875    7.91    62433.930     895.8       87.8        0.10
     9     AGRICULTURE         90246.125    3.99    86780.125     790.7       79.0        0.00
     10     HOME & REC        619217.562   10.96   558060.437    1887.9      100.0        3.23

                                    ** RESOURCE UTILIZATION DATA **

        RESOURCE              UTILIZATION            REMAINING   RECYCLE    THIS CYCLE
     NO.        NAME         USED IN YEAR   % USED  STOCKPILE    RATIO     UNIT COST
     1           IRON            386.30      31.16   12608.39     0.0      0.00005380
     2         COPPER            135.21      28.82   14236.19     0.06     0.00006768
     3      LEAD,ZINC            605.10      36.24   15941.01     0.11     0.00001305
     4        MERCURY            829.58      78.87    3697.66     0.62     0.00000110
     5         SILVER            478.36      96.17     456.21     0.55     0.00021129
     6    TRACE METAL            606.04      32.07   13586.30     0.0      0.00000790
     7           COAL            291.37      48.77    7436.42     0.0      0.00117728
     8            OIL            458.48      54.12    6882.55     0.0      0.00023577
     9    ELECTRICITY           2719.60      27.20    7280.39     0.0      0.00005957
     10                            0.0        0.00        0.0     0.0      0.0
     11        LUMBER            825.85       0.51    9949.27     0.00     0.00016700
     12          FOOD          13347.99      64.50    3552.03     0.0      0.00034465
     13                            0.0        0.0    10000.00     0.0      0.0
     14    URBAN LAND           7877.37      78.77    2122.63     0.0      0.00001930
     15 SUBURBAN LAND           7954.48      79.54    2045.52     0.0      0.00001922
     16   ARABLE LAND           5514.95      36.90    9465.05     0.0      0.00001844
     17                            0.0        0.00        0.0     0.0      0.0
     18     WORK UNITS        128526.44      99.90      96.80     0.0      0.00017259
     19      AIR UNITS          6976.85      69.77    3023.15     0.0      0.0
     20    WATER UNITS          6572.52      65.73    3427.48     0.0      0.0

  ** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1        3.5223       0.1100
    2        0.9133       0.1247
    3        0.4363      -0.1038
    4        1.3753       0.1645
    5        9.6105       0.1380
    6        0.5813       0.0905
    7        1.5033       0.0838
    8        0.3579      -0.2649
    9        0.3159      -0.2147
   10        0.8169      -0.2016
   11        0.7542       0.0734
   12        0.0          0.0

       ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE     SUBS.    STOCKPILE     YEAR
   NUMBER     NUMBER     INCREASE  COMPLETED
     6          0.0      10000.        25

  SHORT TERM FUNCS ADJUSTMENTS

  COMPCNENT  MAINT.AMT     UNITS FRCM
    NUMBER    DEFERRED     EXPORT BAL.
      2        1366.16           0.0
      8        2694.99           0.C
      9        1804.92           5.74
  CUMULATIVE EXPORT BALANCE IS       415680.125

  DEMANC THRESHOLD ADJUSTMENTS

  MEASURE         NEW VALUE
   NUMBER     UPGRADE   DEGRADE
     1        3.3532     0.0
     2        0.8610     0.0
     4        1.2734     0.0
     5        9.0053     0.0
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                   YEAR IS     21

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****STATE  OF  THE  SYSTEM****

                                        ** REGIONAL POPULATION **

AGE GROUP      POPULATION      EDLCATICN      INSTITUTICN      PRFSCHCOL      NON-WORKER      PAID WORKER  UNPAIC WORKER

  TOTAL        253560.500
  <18           71926.312      56189.051         616.788       14964.043         156.429           0.0             0.0
  18-24         25953.852      10219.258         364.318           0.0           753.170       12106.273        2510.842
  25-65        127100.937          0.0          1360.796           0.0          1860.496       86030.125       37849.508
  >65           28579.324          C.0          1200.079           0.0         27379.242           0.0             0.0

                                ** COMPONENT OPERATING DATA  **

     COMPONENT              OPERATING    MAINT.    PRODUCTION     OUTPUT     CAPITAL    ANNUAL %
  NO.        NAME          FUNDS(1000$)  COST(%)   FUNDS(1000$)              % USED    EXPANSION
  1      EDUCATION         297770.000     5.74     281611.187     2833.7      100.0       5.08
  2 TRANSPORTATION          28252.285    10.05      25673.336     1127.4      100.0       0.57
  3         HEALTH         181502.250    13.21     160326.875     3793.6      100.0       6.55
  4   DEFENSE&OTHER        302545.875     6.14     285045.000     1550.0      100.0       2.11
  5        WELFARE         854015.437     7.89     791537.875     3109.0      100.0       5.55
  6   HVY POLLUTING        533617.187     8.94     489818.812     1511.1      100.0       1.99
  7   LGT POLLUTING        331703.312     7.90     307425.875     1516.8      100.0       2.00
  8      COMMERCIAL         68857.062     7.91      63807.422      915.3       89.7       0.10
  9     AGRICULTURE         90516.750     3.99      87040.312      770.9       77.1       0.00
  10     HOME & REC        642747.250    11.10     578550.187     1809.6       95.9       3.07

                              ** RESOURCE UTILIZATION DATA **

      RESOURCE            UTILIZATION           REMAINING    RECYCLE    THIS CYCLE
  NO.         NAME       USED IN YEAR    % USED STOCKPILE      RATIO     UNIT COST
   1          IRON          40C.79       31.30   13407.85       0.0      0.00005380
   2        COPPER          139.08       29.47   14105.27       0.07     0.00006768
   3     LEAD,ZINC          642.60       38.56   15359.50       0.12     0.00001366
   4       MERCURY          873.07       81.95    3159.41       0.67     0.00000110
   5        SILVER          518.55       98.17     219.63       0.58     0.00199200
   6   TRACE METAL          740.78       34.12   13814.72       0.0      0.00000790
   7          COAL          313.27       49.28    7607.76       0.0      0.00117728
   8           OIL          477.72       57.30    6404.83       0.0      0.00025562
   9   ELFCTRICITY         2707.49       27.07    7292.51       0.0      0.00005957
  10                          C.0         0.00       0.0        0.0      0.0
  11        LUMBER          816.17        0.96    9904.04       0.00     0.00016700
  12          FOOD        12815.14       82.34    1767.04       0.0      0.00040840
  13                          0.0         0.0    10000.00       0.0      0.0
  14    URBAN LAND         7669.74       76.70    2330.26       0.0      0.00001930
  15 SUBURBAN LAND         7796.92       77.97    2203.08       0.0      0.00001924
  16   ARABLE LAND         5396.55       35.98    9603.45       0.0      0.00001844
  17                          C.0         0.00       0.0        0.0      0.0
  18    WORK UNITS       136583.C0       99.90      98.14       0.0      0.00017259
  19     AIR UNITS         7086.63       70.87    2913.37       0.0      0.0
  20   WATER UNITS         6547.96       65.48    3452.04       0.0      0.0

** SATISFACTICN OF DFMANDS **
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MEASURE      PRESENT       PRESENT
 NUMBER       VALUE      RESILIENCE
    1         3.7066        0.1054
    2         0.9708        0.1275
    3         0.4446       -0.0866
    4         1.4961        0.1749
    5        10.3120        0.1451
    6         0.5971        0.1201
    7         1.5427        0.1122
    8         0.3610       -0.2585
    9         0.3040       -0.2441
   10         0.7856       -0.2322
   11         0.7137        0.0157
   12         0.0           0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT    UNITS FRCM
   NUMBER    DEFERRED    EXPORT BAL.
      2       1412.61         0.0
      8       2754.28         0.0
      9       1810.33         9.95
  CUMULATIVE EXPORT BALANCE IS       489131.562

  DEMAND THRESHOLD ADJUSTMENTS

  MEASURE        NEW VALUE
   NUMBER     UPGRADE  DEGRADE
      1        3.5223    0.0
      2        0.9133    0.0
      4        1.3753    0.0
      5        9.6105    0.0
      6        0.5813    0.0
      7        1.5033    0.0
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                                   YEAR IS    22

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    ****STATE  OF  THE  SYSTEM****

                                           ** REGIONAL POPULATION **

AGE GROUP      POPULATION      ECUCATICN      INSTITUTION      PRESCHOOL      NON-WORKER      PAID WORKER  UNPAID WORKER

  TOTAL        256845.750
  <18           72913.250      58303.746        650.484       13795.227        163.786           0.0            0.0
  18-24         26410.008      10633.184        386.094           0.0          793.218       12270.367       2327.158
  25-65        128643.250          0.0         1469.902           0.0         2003.682       89288.187      35881.473
  >65           28879.000          0.0         1203.283           0.0        27675.715           0.0            0.0

                                     ** COMPONENT OPERATING DATA  **

      COMPONENT              OPERATING    MAINT.    PRODUCTION     OUTPUT      CAPITAL    ANNUAL %
  NO.        NAME          FUNDS(1000$)  COST(%)   FUNDS(1000$)                % USED    EXPANSION
  1      EDUCATION           322187.062     5.68     304873.750     3066.8      100.0        5.23
  2 TRANSPORTATION            29212.844    10.16      26518.723     1164.0      100.0        0.69
  3          HEALTH          199470.750    13.47     175787.312     2382.8       62.8        6.25
  4  DEFENSE&OTHER           317677.125     6.34     298748.312     1624.5      100.0        2.23
  5        WELFARE           929168.187     7.94     860824.375     3381.1      100.0        5.69
  6  HVY POLLUTING           558657.125     9.25     511389.312     1006.4       66.6        1.89
  7  LGT POLLUTING           346961.500     7.99     321276.250     1581.8      100.0        2.11
  8     COMMERCIAL            70371.812     7.91      65211.086      899.6       88.1        0.09
  9    AGRICULTURE            90788.187     3.99      87301.375      698.9       69.9        0.00
  10    HOME & REC           667171.062    10.34     604652.687     1467.1       77.7        2.93

                                    ** RESOURCE UTILIZATION DATA **

       RESOURCE           UTILIZATION            REMAINING   RECYCLE    THIS CYCLE
  NO.         NAME      USED IN YEAR   % USED  STOCKPILE     RATIO     UNIT COST
   1          IRON          294.91      32.01    13597.54     0.0      0.00005391
   2        COPPER           95.76      29.92    14015.37     0.07     0.00006768
   3     LEAD,ZINC          487.27      40.30    14924.03     0.13     C.00001424
   4       MERCURY          638.32      84.13     2777.53     0.71     0.00000110
   5        SILVER          336.79      99.95        6.23     0.60    89.0606232
   6   TRACE METAL          522.90      28.83    18952.94     0.0      0.00000790
   7          COAL          271.38      51.09     7336.37     0.0      0.00117728
   8           OIL          424.23      60.13     5980.60     0.0      0.00027578
   9   ELECTRICITY         2394.58      23.95     7605.41     0.0      0.00005957
  10                          0.0        0.00        0.0      0.0      0.0
  11        LUMBER          722.39       1.19     9880.63     0.00     0.00016701
  12          FOOD        10507.81      87.41     1259.40     0.0      0.00045435
  13                          0.0        0.0     10000.00     0.0      0.0
  14    URBAN LAND         6577.49      65.77     3422.51     0.0      0.00001930
  15 SUBURBAN LAND         6604.36      66.04     3395.65     0.0      0.00001924
  16   ARABLE LAND         4892.62      32.62    10107.37     0.0      0.00001844
  17                          0.0        0.00        0.0      0.0      0.0
  18    WORK UNITS       138000.69      99.90      101.56     0.0      0.00017259
  19     AIP UNITS         5807.89      58.08     4192.11     0.0      0.0
  20   WATER UNITS         5750.72      57.51     4249.28     0.0      0.0

** SATISFACTION OF DEMANDS **
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MEASURE     PRESENT      PRESENT
 NUMBER      VALUE     RESILIENCE
    1        3.8389      0.0899
    2        1.0303      0.1281
    3        0.4532     -0.0691
    4        0.9277     -0.3254
    5       11.0363      0.1484
    6        0.5039     -0.1332
    7        1.2743     -0.1524
    8        0.3503     -0.2805
    9        0.2721     -0.3235
   10        0.6882     -0.3274
   11        0.5712     -0.1871
   12        0.0          0.0

       ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.    STOCKPILF     YEAR
   NUMBER    NUMBER     INCREASE  CCMPLETED
     5         0.0       1000.        27

  SHORT TERM FUNCS ADJUSTMENTS

  CCMPCNENT  MAINT.AMT     UNITS FRCM
   NUMBER     DEFERRED    EXPORT EAL.
      2        1460.64         0.0
      3        5984.12         0.0
      6       16760.91         0.12
      7       13878.46         0.C
      8        2814.87         0.09
      9        1815.76         0.05
     10       20015.12         0.C
 CUMULATIVE EXPORT BALANCE IS              0.0

 LONG TERM ADJUSTMENTS

 CCMPONENT   1: NEW I/C FCRMULA AC.   2  : CCMPLETF IN YR.  32
 COMPONENT   5: NEW I/O FORMULA NC.   7  : COMPLETF IN YR.  27
 CCMPCNENT   8: NEW I/C FCRMULA AC.  14  : COMPLETE IN YR.  42
 NEW FUND ANNUAL GROWTH RATES
  (COMPCNENT NO. -- RATE)

  1-- 8.20   2-- 3.40   3-- 9.90   4-- 5.00    5-- 8.80
  6-- 5.91   7-- 3.19   8-- 5.16   9-- 4.02   10-- 2.72
 DEMAND THRESHOLD ADJUSTMENTS

 MEASURE        NEW VALUE
  NUMBEI    UPGRADE  DEGRADE
    2        0.9708    0.0
    5       10.3120    0.0
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                                   YEAR IS    23

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    ****STATE  OF  THE  SYSTEM****


                                              ** REGICNAL POPULATION **

AGE GROUP     POPULATION     ECUCATICN     INSTITUTICN     PRESCHOCL     NCN-WORKER     PAID WCRKER   UNPAID WORKER

 TCTAL        26C173.562
 <18           73912.187      62246.309        418.867     11070.691        176.316           0.0             0.0
 18-24         26906.625      12069.895        267.464           0.0        912.365     11662.516        1994.383
 25-65        130189.062            0.0       1113.111           0.0       2547.005     92536.250       33992.656
 >65           29165.574            0.0        816.797           0.0      2834E.777           0.0             0.0

                                   ** COMPONENT OPERATING DATA  **

      COMPONENT
  NO.       NAME          OPERATING      MAINT.    PRODUCTION      OUTPUT     CAPITAL     ANNUAL %
                        FUNDS(1000$)    CCST(%)   FUNDS(1000$)                % USED     EXPANSION
  1       EDUCATION      3486C6.312       6.00     328867.812     3360.2      100.0        5.41
  2 TRANSPORTATICN        30206.062      10.27      27392.906     1201.7      100.0        0.80
  3          HEALTH      219218.125      15.26     190195.937     4489.9      100.0        6.75
  4   DEFENSE&OTHER      333560.687       6.72     312566.125     1659.6      100.0        2.33
  5         WELFARE      1010934.37       8.35     933048.875     3846.5      100.0        6.03
  6   HVY POLLUTING      5917C6.062       8.61     544823.437     1676.5      100.0        2.27
  7   LGT POLLUTING      358024.375      12.31     318768.625     1566.3       99.0        2.01
  8      COMMERCIAL       74005.500       7.80      68648.437      984.0       96.4        0.09
  9     AGRICULTURE       9443E.125       3.92      90873.437      710.2       71.0        0.00
 10      HOME & REC      685331.937       2.13     611219.687     1404.3       74.4        2.80

                                   ** RESOURCE UTILIZATICN DATA **

      RESOURCE
  NO.       NAME        UTILIZATICN             REMAINING    RECYCLE     THIS CYCLE
                        USED IN YEAR   % USED   STOCKPILE     RATIO      UNIT COST
  1            IRON        437.51      34.20    13160.04      0.0       0.00005438
  2          COPPER        145.89      30.63    13874.91      0.07      0.00006768
  3       LEAD,ZINC        715.00      42.83    14291.26      0.15      0.00001482
  4         MERCURY        939.22      87.27     2227.56      0.76      0.00000110
  5          SILVER        602.65      99.90       12.10      0.60     12.4825945
  6     TRACE METAL        828.54      31.94    18124.40      0.0       0.00000790
  7            COAL        351.57      53.43     6984.80      0.0       0.00117728
  8             OIL        509.53      63.53     5471.07      0.0       0.00029786
  9     ELECTRICITY       3190.45      31.90     6809.54      0.0       0.00005957
 10                          0.0        0.00        0.0       0.0       0.0
 11          LUMBER        706.77       1.16     9884.12      0.00      0.00016701
 12            FOOD      10123.89      87.04     1296.88      0.0       0.00046486
 13                          0.0        0.0     10000.00      0.0       0.0
 14      URBAN LAND       645E.51      64.59     3541.09      0.0       0.00001930
 15   SUBURBAN LAND       6742.25      67.42     3257.75      0.0       0.00001924
 16     ARABLE LANC       4971.49      33.14    10028.51      0.0       0.00001844
 17                          0.0        0.00        0.0       0.0       0.0
 18      WORK UNITS     154065.00      99.90      104.20      0.0       0.00017259
 19       AIR UNITS       7160.71      71.61     2839.29      0.0       0.0
 20     WATER UNITS       6092.71      60.93     3907.29      0.0       0.0

** SATISFACTION OF DEMANDS **
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 MEASURE    PRESENT
  NUMBER     VALUE      PRESENT
                       RESILIENCE
     1       3.9012      0.1076
     2       1.1143      0.1479
     3       0.4619     -0.0511
     4       1.7257      0.2548
     5      12.0261      0.1662
     6       0.6232      0.0721
     7       1.5561      0.0351
     8       0.3782     -0.2231
     9       0.2730     -0.3214
    10       0.6816     -0.3339
    11       0.5398     -0.2318
    12       0.0         0.0
      ****ADJUSTMENTS  OF  SYSTEM****

**RESOURCE ADJUSTMENTS**

  RESOURCE    SUBS.
  NUMBER     NUMBER    STOCKPILE     YEAR
     2         0.0      INCREASE   COMPLETED
                        5000.         28

  SHORT TERM FUNDS ADJUSTMENTS

  COMPONENT  MAINT.AMT
   NUMBER    DEFERRED     UNITS FROM
     2        1510.30     EXPORT BAL.
               2960.22        0.0
               1888.76        2.86
              20559.95        2.08
 CUMULATIVE EXPORT BALANCE IS 0.0
                                        0.0
 LONG TERM ADJUSTMENTS

 NEW FUND ANNUAL GROWTH RATES
  (COMPONENT NO. — RATE)

 1— 8.20    2— 3.40    3-- 9.90
 6— 5 91    7-- 3.19   8-- 5.16    4-- 5.00    5-- 8.80
DEMAND THRESHOLD ADJUSTMENTS       9-- 4.02   10-- 2.72

MEASURE         NEW VALUE
 NUMBER     UPGRADE  DEGRADE
   1         3.8389    0.0
   2         1.0303    0.0
   5        11.0363    0.0
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                                   YEAR IS    24

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    ****STATE  OF  THE  SYSTEM****

                                       ** REGICNAL POPULATION **

AGE GROUP     POPULATION      ECUCATION     INSTITUTION     PRESCHOOL      NCN-WORKER     PAID WORKER  UNPAID WORKER

  TCTAL      263544.500
   <18        74923.125      64067.684        711.782        9955.215        188.438           0.0            0.0
  18-24       27448.703      11739.871        426.117           0.0          921.542       12667.141      1694.040
  25-65      131733.062          0.0         1726.803           0.0         2499.936       99441.375     28064.910
   >65        29439.527          0.0         1148.529           0.0        28291.000           0.0            0.0

                              ** COMPONENT OPERATING DATA  **

      COMPONENT          OPERATING     MAINT.    PRODUCTION     OUTPUT     CAPITAL     ANNUAL %
  NO.        NAME       FUNDS(1000$)   COST(%)   FUNDS(1000$)              % USED     EXPANSION
  1      EDUCATION       377151.937     6.40     354508.062     3734.5      100.0        5.64
  2 TRANSPORTATICN        31233.051    10.38      28296.863     1240.7      100.0        0.90
  3         HEALTH       240920.500    14.34     210700.187     4968.5      100.0        6.91
  4   DEFENSE&OTHER      350238.437     7.06     327142.625     1778.9      100.0        2.43
  5        WELFARE       1099855.00     9.18     1007376.75     5845.1      100.0        7.63
  6   HVY POLLUTING      626665.250    10.65     566359.000     1740.0      100.0        2.33
  7   LGT POLLUTING      369440.000     8.32     341074.437     1671.9      100.0        2.16
  8      COMMERCIAL       77826.812     7.80      72193.187     1034.2      100.0        0.14
  9     AGRICULTURE       98234.812     3.92      94526.812      753.8       75.3        0.00
  10     HOME & REC      703987.125    11.32     632377.125     1524.1       80.7        2.68

                              ** RESOURCE UTILIZATICN DATA **

        RESOURCE         UTILIZATICN              REMAINING     RECYCLE     THIS CYCLE
  NO.        NAME       USED IN YEAR    % USED    STCCKPILE      RATIO      UNIT COST
   1          IRON          455.58       36.48     12704.45       0.0       0.00005513
   2        COPPER          155.99       30.61     14213.78       0.07      0.00006768
   3     LEAD,ZINC          754.62       45.47     13633.22       0.17      0.00001557
   4       MERCURY         1021.94       90.59      1647.44       0.82      0.00000110
   5        SILVER          656.39       98.68       167.66       0.58      0.00529633
   6   TRACE METAL          891.41       32.37     19633.48       0.0       0.00000790
   7          COAL          426.05       56.27      6558.75       0.0       0.00117728
   8           OIL          545.02       67.19      4922.06       0.0       0.00032423
   9   ELECTRICITY         4157.04       41.57      5842.96       0.0       0.00005957
  10                          0.0         0.00         0.0        0.0       0.0
  11        LUMBER          763.18        1.25      9874.75       0.00      0.00016701
  12          FOOD        10960.38       88.80      1121.03       0.0       0.00046808
  13                          0.0         0.0      10000.00       0.0       0.0
  14    URBAN LAND         6921.97       69.22      3078.03       0.0       0.00001930
  15 SUBURBAN LAND         7219.16       72.19      2780.84       0.0       0.00001924
  16   ARABLE LAND         5276.38       35.18      9723.62       0.0       0.00001844
  17                          0.0         0.00         0.0        0.0       0.0
  18    WORK UNITS       163864.00       99.90       112.11       0.0       0.00017259
  19     AIR UNITS         7485.45       74.85      2514.55       0.0       0.0
  20   WATER UNITS         6495.83       64.96      3504.17       0.0       0.0

 ** SATISFACTION OF DEMANDS **
```

```
MEASURE      PRESENT      PRESENT
 NUMBER       VALUE     RESILIENCE
    1        4.2352       0.1033
    2        1.2183       0.1824
    3        0.4708      -0.0329
    4        1.8853       0.3708
    5       18.3227       C.6602
    6        0.6473       0.1135
    7        1.5217       0.0122
    8        0.3924      -0.1939
    9        0.2860      -0.2890
   10        0.6724      -0.3429
   11        0.5783      -0.1769
   12        0.0          0.0

      ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  SHORT TERM FUNCS ADJUSTMENTS

  COMPONENT  MAINT.AMT     UNITS FRCM
    NUMBER    DEFERREC     EXPORT BAL.
       2       1561.65           0.0
       8       3113.07           0.0
       9       1964.70          23.58
      10      21119.61           0.0
  CUMULATIVE EXPORT BALANCE IS         6283.6562

  DEMAND THRESHOLD ADJUSTMENTS

  MEASURE        NEW VALUE
   NLMBER    UPGRADE  DEGRADE
     1        3.9012   0.0
     2        1.1143   0.0
     4        1.7257   0.0
     5       12.0261   0.0
     6        0.6232   0.0
```

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***********************************************

                  YEAR IS    25

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****STATE  OF  THE  SYSTEM****

                                      ** REGIONAL POPULATION **

AGE GROUP     POPULATION      EDUCATION     INSTITUTION     PRESCHOOL     NON-WORKER     PAID WORKER  UNPAID WORKER

  TOTAL       266959.125                                                                                          
   <18         75945.625      65071.977        719.073      9892.391        262.176          0.0            0.0
  18-24        27823.953      11566.965        432.936         0.0         1290.215      12440.855       1692.996
  25-65       133488.062         0.0          1789.628         0.0         3566.021      99548.562      28583.836
   >65         29701.375         0.0           842.749         0.0        28858.625          0.0            0.0

                               ** COMPONENT OPERATING DATA  **

      COMPONENT            OPERATING   MAINT.    PRODUCTION    OUTPUT    CAPITAL   ANNUAL %
NO.       NAME           FUNDS(1000$)  COST(%)  FUNDS(1000$)             % USED    EXPANSION
1       EDUCATION          408121.562    6.60    382852.875    4243.4     100.0      5.95
2 TRANSPORTATION            32294.957   10.48     29231.715    1280.7     100.0      0.99
3          HEALTH          264771.375   14.27    231716.187    5454.4     100.0      7.02
4  DEFENSE&OTHER           367750.062    7.39    342446.125    1862.1     100.0      2.52
5         WELFARE          1196685.00   13.27    1056445.00    6129.8     100.0      7.52
6  HVY POLLUTING           663689.875   11.05    597665.312    1831.8     100.0      2.45
7  LGT POLLUTING           381219.625    8.93    349972.937    1710.3     100.0      2.17
8      COMMERCIAL           81845.437    8.20     75644.562    1082.7     100.0      0.32
9     AGRICULTURE          102184.125    3.92     98327.062     786.1      78.6      0.00
10     HOME & REC          723150.125   10.93    651911.875    1583.5      83.9      2.57

                             ** RESOURCE UTILIZATION DATA **

     RESOURCE            UTILIZATION             REMAINING   RECYCLE    THIS CYCLE
NO.      NAME           USED IN YEAR    % USED   STOCKPILE    RATIO     UNIT COST
 1           IRON           477.57      38.87    12226.89     0.0      0.00005596
 2         COPPER           163.77      27.55    16891.32     0.06     0.00006768
 3      LEAD,ZINC           798.21      48.21    12948.29     0.19     0.00001637
 4        MERCURY          1097.34      94.03     1044.70     0.88     0.00000291
 5         SILVER           712.98      99.90       12.66     0.60    12.4825945
 6    TRACE METAL           953.40      34.51    19647.29     0.0      0.00000799
 7           COAL            46 .78     59.38     6092.96     0.0      0.00117728
 8            OIL           587.25      71.10     4334.81     0.0      0.00035416
 9    ELECTRICITY          4602.29      46.02     5397.71     0.0      0.00005957
10                            0.0        0.00        0.0      0.0      0.0
11         LUMBER           792.31       1.31     9868.56     0.00     0.00016701
12           FOOD         11392.24      90.25      975.37     0.0      0.00049139
13                            0.0        0.0     10000.00     0.0      0.0
14     URBAN LAND          7187.16      71.87     2812.84     0.0      0.00001930
15  SUBURBAN LAND          7498.53      74.99     2501.47     0.0      0.00001924
16    ARABLE LAND          5502.44      36.68     9497.56     0.0      0.00001844
17                            0.0        0.00        0.0      0.0      0.0
18     WORK UNITS        173147.15      99.90      111.99     0.0      0.00017259
19      AIR UNITS          7808.58      78.09     2191.42     0.0      0.0
20    WATER UNITS          6735.98      67.36     3264.02     0.0      0.0

** SATISFACTION OF DEMANDS **
```

```
 MEASURE   PRESENT      PRESENT
 NUMBER     VALUE      RESILIENCE
    1       4.7121       0.2079
    2       1.3598       0.2203
    3       0.4797      -0.0145
    4       2.0432       0.1840
    5      18.0411       0.5002
    6       0.6634       0.0645
    7       1.5814       0.0520
    8       0.4056      -0.1669
    9       0.2945      -0.2680
   10       0.7019      -0.3140
   11       0.5932      -0.1558
   12       0.0          0.0

        ****ADJUSTMENTS  OF  SYSTEM****


**RESOURCE ADJUSTMENTS**

  RESOURCE     SUBS.     STOCKPILE      YEAR
   NUMBER     NUMBER      INCREASE   COMPLETED
     4          0.0        2500.         30

  SHORT TERM FUNDS ADJUSTMENTS

  CCMPCNENT   MAINT.AMT    UNITS FROM
   NUMBER     DEFERRED    EXPORT EAL.
     2         1614.75          0.0
     8         3273.82          5.47
     9         2043.68          5.11
    10        21694.49          0.0
  CUPULATIVE EXPORT BALANCE IS             0.0

  LONG TERM ADJUSTMENTS

  NEW FUND ANNUAL GROWTH RATES
   (COMPONENT NO. -- RATE)

   1-- 8.20    2-- 3.40    3-- 9.90    4-- 5.00     5-- 8.80
   6-- 5.91    7-- 3.19    8-- 5.16    9-- 4.02    10-- 2.72
  DEMAND THRESHOLD ADJUSTMENTS

  MEASURE         NEW VALUE
   NUMBER    UPGRADE   DEGRADE
     1        4.2352     0.0
     2        1.2183     0.0
     4        1.8853     0.0
```

SUMMARY TABLE - STATE OF THE SYSTEM
(SCALED TO ORIGINAL VALUE)

YEAR	POPULATION (P)	PUBLIC FUNDS (G)	PRIVATE FUNDS (I)	QUALITY LEVEL (Q)	NATURAL ORE USAGE (N)	ENERGY USAGE (E)	FARM AND LAND USAGE (F)	EMPLOYED WORKERS (U)	TREATED ECO-MEDIA (M)
1.	1.0109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0211	1.0848	1.0371	1.0310	1.0478	1.0450	1.0270	1.0504	1.0308
3.	1.0329	1.1612	1.0670	0.8296	0.8302	0.8321	0.9469	0.7976	0.8631
4.	1.0342	1.2302	1.0884	0.9636	0.9500	0.9645	1.0109	0.9506	0.9599
5.	1.0442	1.3402	1.1261	0.9918	1.0090	1.0161	1.0369	1.0031	0.9917
6.	1.0544	1.4769	1.1657	1.0289	1.0503	1.0670	1.0641	1.0636	1.0245
7.	1.0663	1.5851	1.2056	1.0548	1.0920	1.1113	1.0900	1.1138	1.0543
8.	1.0794	1.7094	1.2631	0.8748	0.9098	0.8901	1.0289	0.8773	0.9160
9.	1.0824	1.8195	1.2906	1.0143	1.0586	0.9992	1.0935	1.0495	1.0174
10.	1.0945	2.0174	1.3363	1.0528	1.1262	1.0580	1.1239	1.1172	1.0512
11.	1.1071	2.1841	1.3831	1.0878	1.1777	1.1097	1.1537	1.1801	1.0834
12.	1.1215	2.3592	1.4511	0.9061	0.9870	0.9395	1.0972	0.9384	0.9499
13.	1.1257	2.5277	1.4934	1.0600	1.1678	1.1358	1.1716	1.1284	1.0593
14.	1.1403	2.8152	1.5470	1.1055	1.2628	1.2662	1.2075	1.2096	1.0951
15.	1.1550	3.0372	1.6048	1.1451	1.3614	1.4158	1.2459	1.2789	1.1332
16.	1.1700	3.2941	1.6867	1.1959	1.5018	1.6099	1.2863	1.3578	1.1844
17.	1.1851	3.5823	1.7427	1.2467	1.6394	1.8443	1.3264	1.4416	1.2225
18.	1.2005	3.8883	1.8080	1.3013	1.7950	2.0512	1.3689	1.5319	1.2666
19.	1.2161	4.2057	1.8725	1.3559	1.9441	2.2446	1.4099	1.6239	1.3104
20.	1.2318	4.5535	1.9405	1.4136	2.0912	2.4518	1.4549	1.7229	1.3549
21.	1.2478	4.9514	2.0116	1.4583	2.2280	2.6108	1.4181	1.8309	1.3635
22.	1.2639	5.3795	2.0949	1.3034	1.5974	2.2721	1.2165	1.8499	1.1559
23.	1.2803	5.8179	2.1535	1.5168	2.4748	2.9227	1.2063	2.0652	1.3253
24.	1.2969	6.2952	2.2487	1.7338	2.6421	3.5159	1.2961	2.1966	1.3981
25.	1.3137	6.6859	2.3369	1.8205	2.8169	3.8390	1.3468	2.3210	1.4545

STATE OF THE SYSTEM

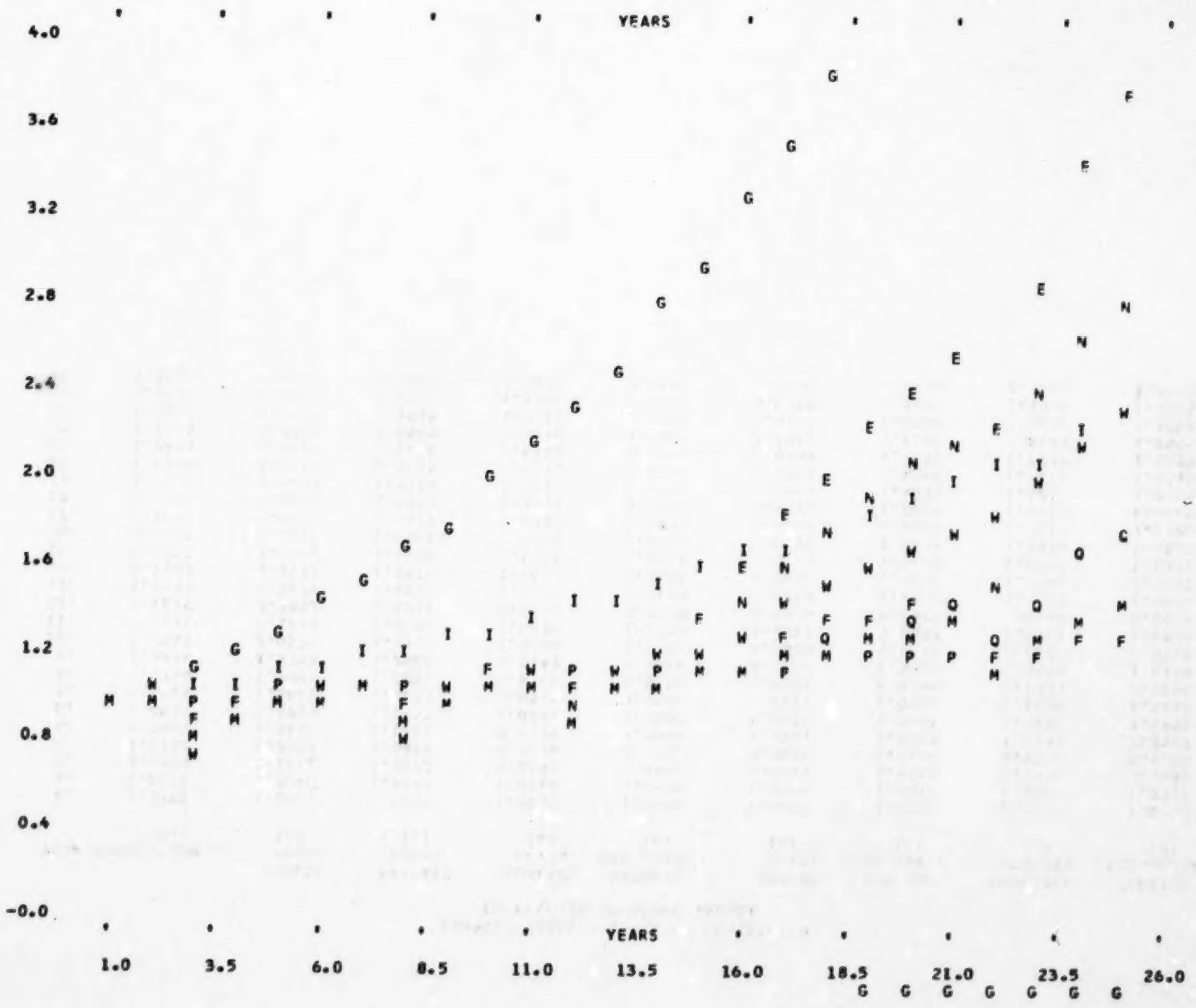

TABLE NUMBER ONE - POPULATION
(SCALED TO ORIGINAL VALUE)

YEAR	TOTAL POPULATION (P)	UNDER 18 YEARS (1)	18-24 YEARS (2)	25-64 YEARS (3)	OVER 64 YEARS (4)
1.	1.0109	0.3417	0.1237	0.4435	0.1019
2.	1.0211	0.3407	0.1258	0.4498	0.1048
3.	1.0329	0.3403	0.1282	0.4570	0.1075
4.	1.0342	0.3367	0.1291	0.4596	0.1087
5.	1.0442	0.3331	0.1345	0.4659	0.1107
6.	1.0544	0.3296	0.1398	0.4724	0.1125
7.	1.0663	0.3268	0.1455	0.4797	0.1142
8.	1.0794	0.3245	0.1490	0.4899	0.1159
9.	1.0824	0.3193	0.1512	0.4956	0.1162
10.	1.0945	0.3170	0.1547	0.5058	0.1171
11.	1.1071	0.3149	0.1582	0.5140	0.1200
12.	1.1215	0.3135	0.1590	0.5262	0.1228
13.	1.1257	0.3151	0.1526	0.5337	0.1243
14.	1.1403	0.3157	0.1476	0.5461	0.1269
15.	1.1550	0.3246	0.1425	0.5586	0.1293
16.	1.1700	0.3297	0.1374	0.5713	0.1315
17.	1.1851	0.3351	0.1322	0.5842	0.1336
18.	1.2005	0.3397	0.1280	0.5972	0.1355
19.	1.2161	0.3444	0.1238	0.6105	0.1374
20.	1.2318	0.3492	0.1257	0.6179	0.1391
21.	1.2478	0.3540	0.1277	0.6255	0.1406
22.	1.2639	0.3588	0.1300	0.6331	0.1421
23.	1.2803	0.3637	0.1324	0.6407	0.1435
24.	1.2969	0.3687	0.1351	0.6483	0.1449
25.	1.3137	0.3737	0.1369	0.6569	0.1462

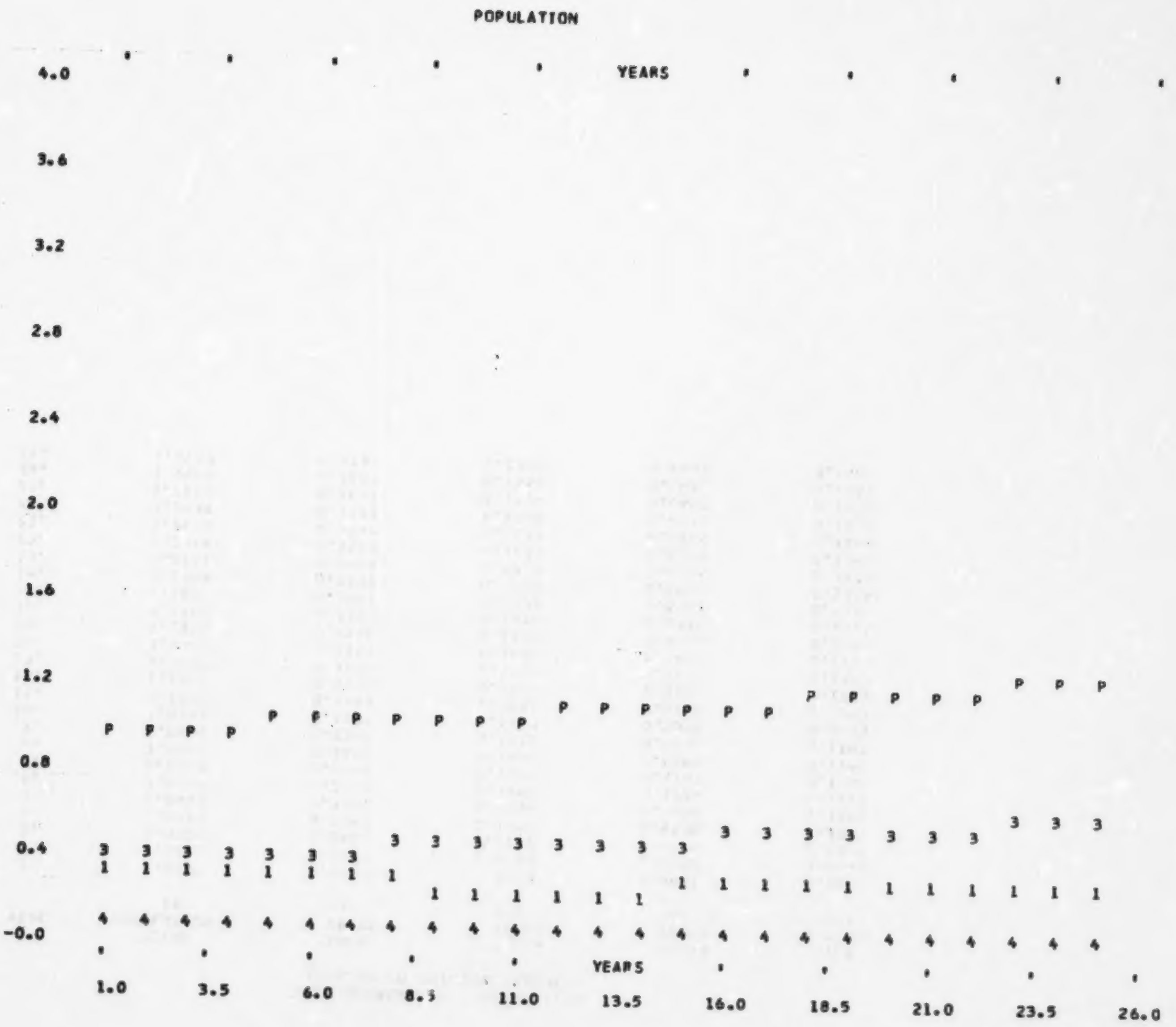POPULATION
YEARS
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
-0.0
YEARS
1.0
3.5
6.0
8.5
11.0
13.5
16.0
18.5
21.0
23.5
26.0

TABLE NUMBER TWO - PUBLIC SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	EDUCATION (E)	TRANSPORTATION (T)	HEALTH (H)	DEFENSE AND OTHER (D)	WELFARE (W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0819	1.0328	1.0906	1.0500	1.0880
3.	0.8308	0.7644	0.8580	0.7785	0.8323
4.	1.0294	0.8803	1.0657	0.9560	1.0313
5.	1.1146	0.9102	1.2039	1.0042	1.1232
6.	1.2245	0.9411	1.2963	1.0546	1.2503
7.	1.3089	0.9725	1.3892	1.1047	1.3411
8.	1.0417	0.7438	1.1412	0.8479	1.0668
9.	1.2768	0.8846	1.4066	1.0285	1.3073
10.	1.3841	0.9150	1.5898	1.0800	1.4629
11.	1.5167	0.9459	1.7046	1.1329	1.5792
12.	1.2167	0.7305	1.4119	0.8808	1.2700
13.	1.4933	0.8662	1.7571	1.0699	1.5601
14.	1.6485	0.8956	1.9858	1.1227	1.7466
15.	1.7770	0.9256	2.1573	1.1788	1.8884
16.	1.9202	0.9572	2.3750	1.2331	2.0507
17.	2.0804	0.9893	2.6183	1.2900	2.2355
18.	2.2519	1.0226	2.8810	1.3544	2.4312
19.	2.4292	1.0575	3.1468	1.4162	2.6343
20.	2.6208	1.0921	3.4425	1.4815	2.8559
21.	2.8337	1.1274	3.7936	1.5500	3.1090
22.	3.0668	1.1640	2.3828	1.6245	3.3811
23.	3.3602	1.2017	4.4899	1.6996	3.8465
24.	3.7345	1.2407	4.9685	1.7789	5.8451
25.	4.2434	1.2807	5.4544	1.8621	6.1298

TABLE NUMBER THREE - PRIVATE SECTOR OUTPUT UNITS
(SCALED TO ORIGINAL VALUE)

YEAR	HEAVY POLL. MANUFACTURE (H)	LIGHT POLL. MANUFACTURE (L)	COMMERCIAL (C)	AGRICULTURE (F)	HOUSEHOLD & RECREATION (R)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0398	1.0454	1.0208	1.0005	1.0358
3.	0.8039	0.8118	0.7486	0.8443	1.0639
4.	0.9403	0.9378	0.8581	0.9202	1.0989
5.	0.9872	0.9814	0.8771	0.9229	1.1323
6.	1.0352	1.0267	0.8964	0.9256	1.1676
7.	1.0752	1.0658	0.9132	0.9263	1.2027
8.	0.8796	0.8810	0.6939	0.7850	1.2400
9.	1.0230	1.0123	0.8143	0.8379	1.2811
10.	1.0689	1.0602	0.8324	0.8407	1.3221
11.	1.1104	1.1042	0.8492	0.8424	1.3635
12.	0.9119	0.9146	0.6504	0.7095	1.4093
13.	1.0658	1.0538	0.7636	0.7740	1.4640
14.	1.1103	1.1022	0.7809	0.7767	1.5160
15.	1.1591	1.1520	0.7986	0.7790	1.5720
16.	1.2339	1.2426	0.8169	0.7814	1.6321
17.	1.2802	1.2874	0.8369	0.7836	1.6922
18.	1.3405	1.3452	0.8559	0.7862	1.7539
19.	1.3952	1.4007	0.8753	0.7886	1.8210
20.	1.4524	1.4578	0.8958	0.7907	1.8879
21.	1.5111	1.5168	0.9153	0.7709	1.8096
22.	1.0064	1.5818	0.8996	0.6989	1.4671
23.	1.6765	1.5663	0.9840	0.7102	1.4043
24.	1.7400	1.6719	1.0342	0.7538	1.5241
25.	1.8318	1.7103	1.0827	0.7861	1.5835

PRIVATE SECTOR

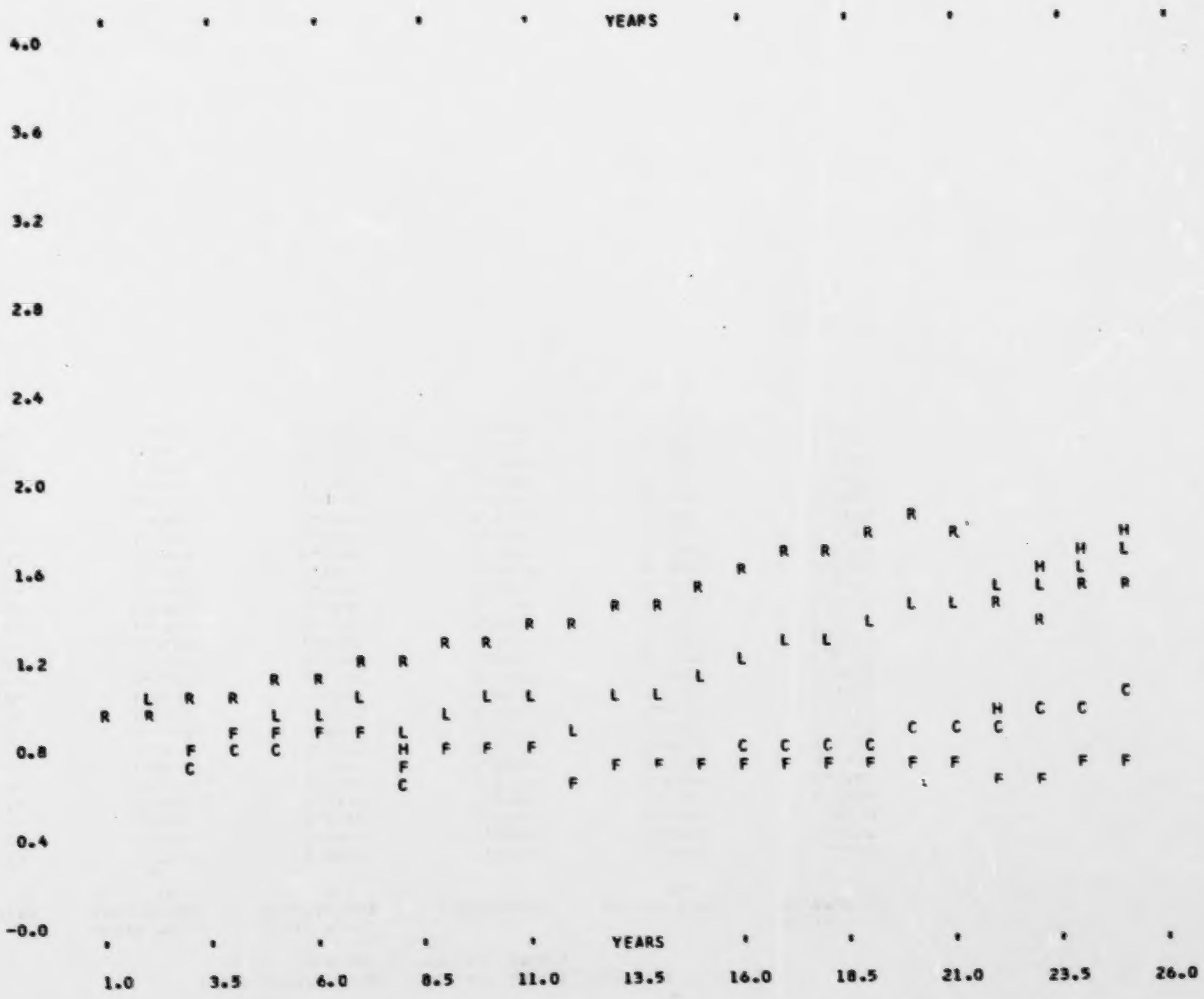

TABLE NUMBER FOUR - NATURAL RESOURCES USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	IRON (I)	COPPER (C)	LEAD AND ZINC (L)	MERCURY (M)	SILVER (S)	TRACE ORES (T)
1.	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0358	1.0404	1.0419	1.0514	1.0633	1.0541
3.	0.8048	0.8047	0.8077	0.8267	0.7614	0.9759
4.	0.9685	0.9036	0.9462	0.6065	0.4671	1.8081
5.	1.2341	0.7249	0.9958	0.6465	0.5093	1.9434
6.	1.2883	0.7600	1.0420	0.5165	0.3197	2.3754
7.	1.4372	0.6862	1.0835	0.4713	0.2432	2.6308
8.	1.2086	0.5279	0.8797	0.4084	0.1984	2.2361
9.	1.3984	0.6132	1.0285	0.4676	0.2388	2.6054
10.	1.4570	0.6408	1.0830	0.5005	0.2611	2.8148
11.	1.5105	0.6659	1.1282	0.5245	0.2763	2.9607
12.	1.2386	0.5473	0.9207	0.4567	0.2272	2.5317
13.	1.4413	0.6302	1.0942	0.5285	0.2762	3.0362
14.	1,4985	0.6399	1.1712	0.5676	0.3030	3.3963
15.	1.5604	0.6399	1.2580	0.6007	0.3244	3.7849
16.	1.6558	0.6410	1.3832	0.6449	0.3526	4.3331
17.	1.7146	0.6149	1.5021	0.6863	0.3810	4.9378
18.	1.7901	0.5912	1.6384	0.7323	0.4125	5.6055
19.	1.8596	0.5688	1.7671	0.7785	0.4438	6.2467
20.	1.9319	0.5568	1.8909	0.8286	0.4784	6.8604
21.	2.0039	0.5563	2.0081	0.8731	0.5186	7.4078
22.	1.4746	0.3830	1.5227	0.6383	0.3368	5.2290
23.	2.1875	0.5996	2.2344	0.9392	0.6026	8.2855
24.	2.2779	0.6239	2.3582	1.0219	0.6564	8.9141
25.	2.3878	0.6551	2.4944	1.0973	0.7130	9.5540

NATURAL RESOURCES

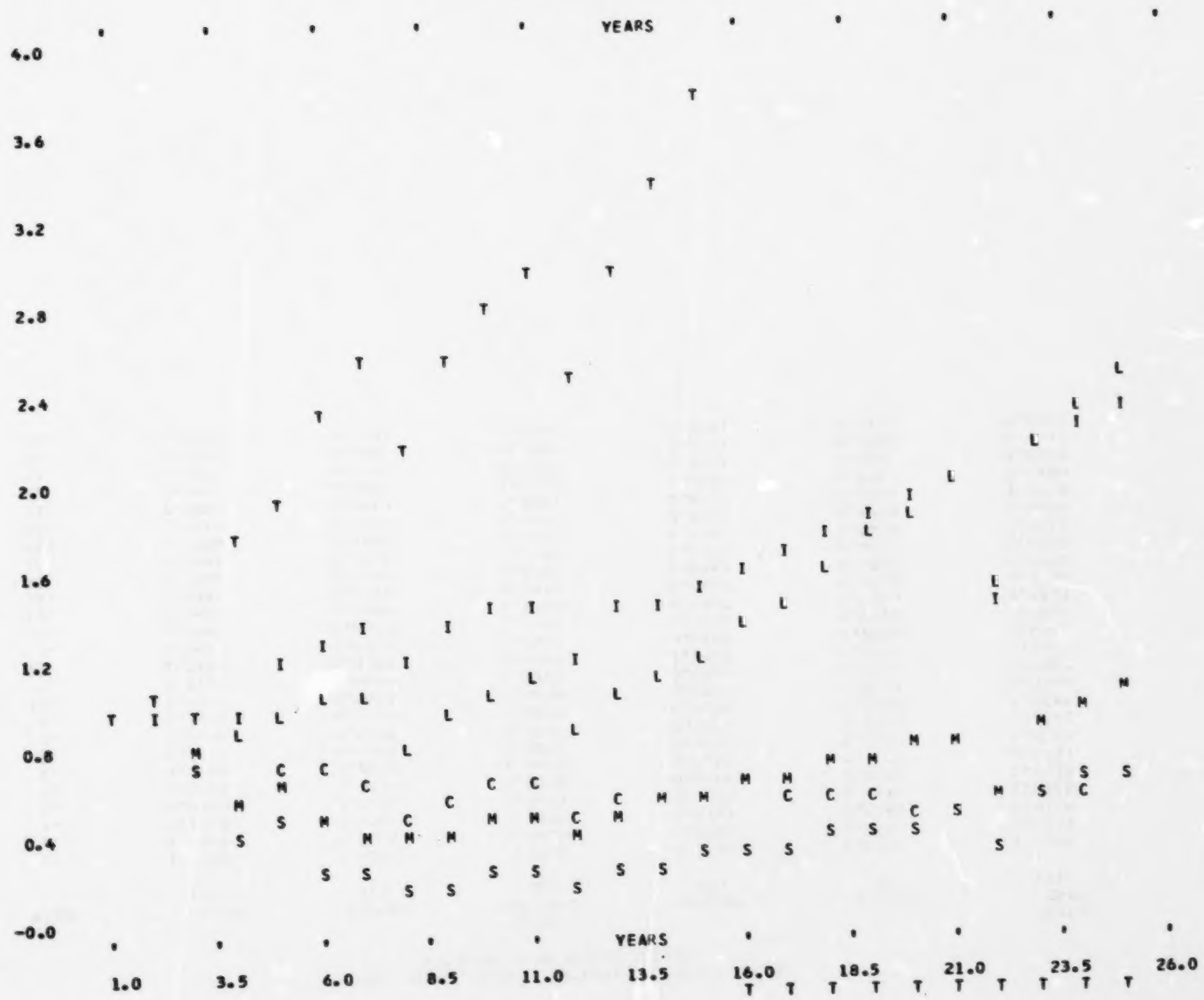

TABLE NUMBER FIVE - ENERGY & AGRICULTURAL USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	COAL (C)	OIL (D)	ELECTRICITY (E)	TIMBER (T)	FOOD (F)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0425	1.0388	1.0539	1.0372	1.0287
3.	0.8306	0.8315	0.8341	0.9568	1.0200
4.	0.9592	0.9517	0.9826	1.0265	1.0631
5.	1.0082	0.9949	1.0452	1.0615	1.0904
6.	1.0562	1.0370	1.1079	1.0982	1.1192
7.	1.0981	1.0744	1.1616	1.1327	1.1475
8.	1.0019	0.7139	0.9545	1.0777	1.1490
9.	1.2590	0.6148	1.1238	1.1538	1.1925
10.	1.3249	0.6452	1.2040	1.1946	1.2259
11.	1.3838	0.6725	1.2728	1.2343	1.2593
12.	1.2264	0.5623	1.0298	1.1850	1.2693
13.	1.5955	0.6508	1.1610	1.2709	1.3260
14.	1.9540	0.6867	1.1579	1.3183	1.3681
15.	2.4383	0.7188	1.0902	1.3687	1.4134
16.	3.0770	0.7604	0.9924	1.4337	1.4620
17.	3.9128	0.7979	0.8222	1.4852	1.5105
18.	4.5929	0.8395	0.7211	1.5415	1.5604
19.	5.2070	0.8815	0.6454	1.6003	1.6145
20.	5.8625	0.9262	0.5666	1.6597	1.6685
21.	6.3031	0.9651	0.5641	1.6323	1.6019
22.	5.4605	0.8570	0.4989	1.4448	1.3135
23.	7.0740	1.0293	0.6647	1.4135	1.2655
24.	8.5725	1.1091	0.8661	1.5264	1.3700
25.	9.3719	1.1864	0.9588	1.5846	1.4240

ENERGY & AGRICULTURE(2)

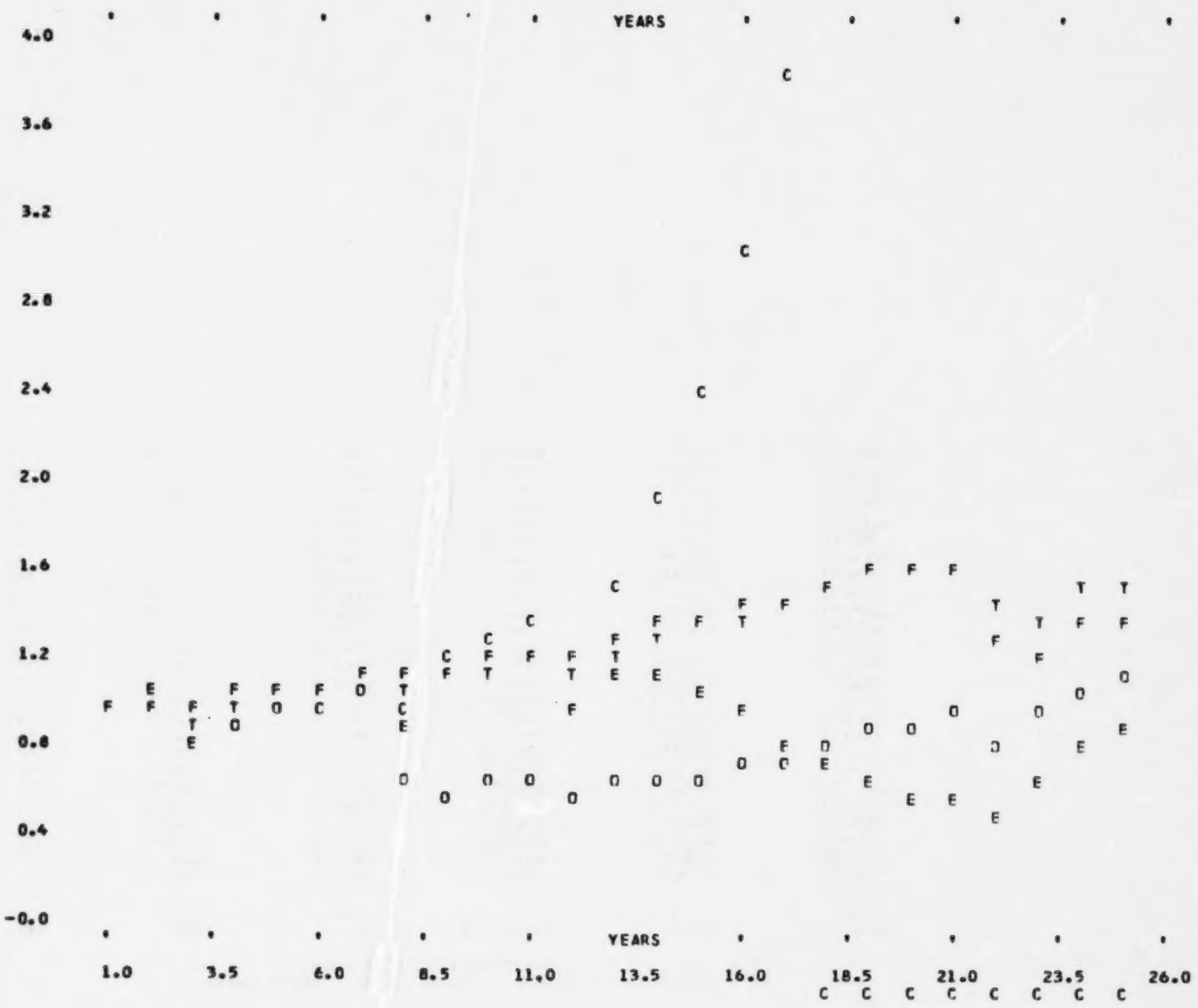

TABLE NUMBER SIX
UNEMPLOYMENT AND QCL VALUES

YEAR	UNEMPLOYMENT (U)	QUALITY (Q)
1.	0.0681	1.3487
2.	0.0355	1.3905
3.	0.2789	1.1189
4.	0.0800	1.2997
5.	0.0768	1.3377
6.	0.0415	1.3877
7.	0.0149	1.4227
8.	0.2427	1.1798
9.	0.0431	1.3680
10.	0.0348	1.4199
11.	0.0010	1.4671
12.	0.2207	1.2222
13.	0.0010	1.4296
14.	0.0010	1.4910
15.	0.0010	1.5445
16.	0.0010	1.6129
17.	0.0010	1.6815
18.	0.0010	1.7551
19.	0.0010	1.8288
20.	0.0010	1.9066
21.	0.0010	1.9668
22.	0.0010	1.7580
23.	0.0010	2.0458
24.	0.0010	2.3385
25.	0.0010	2.4555

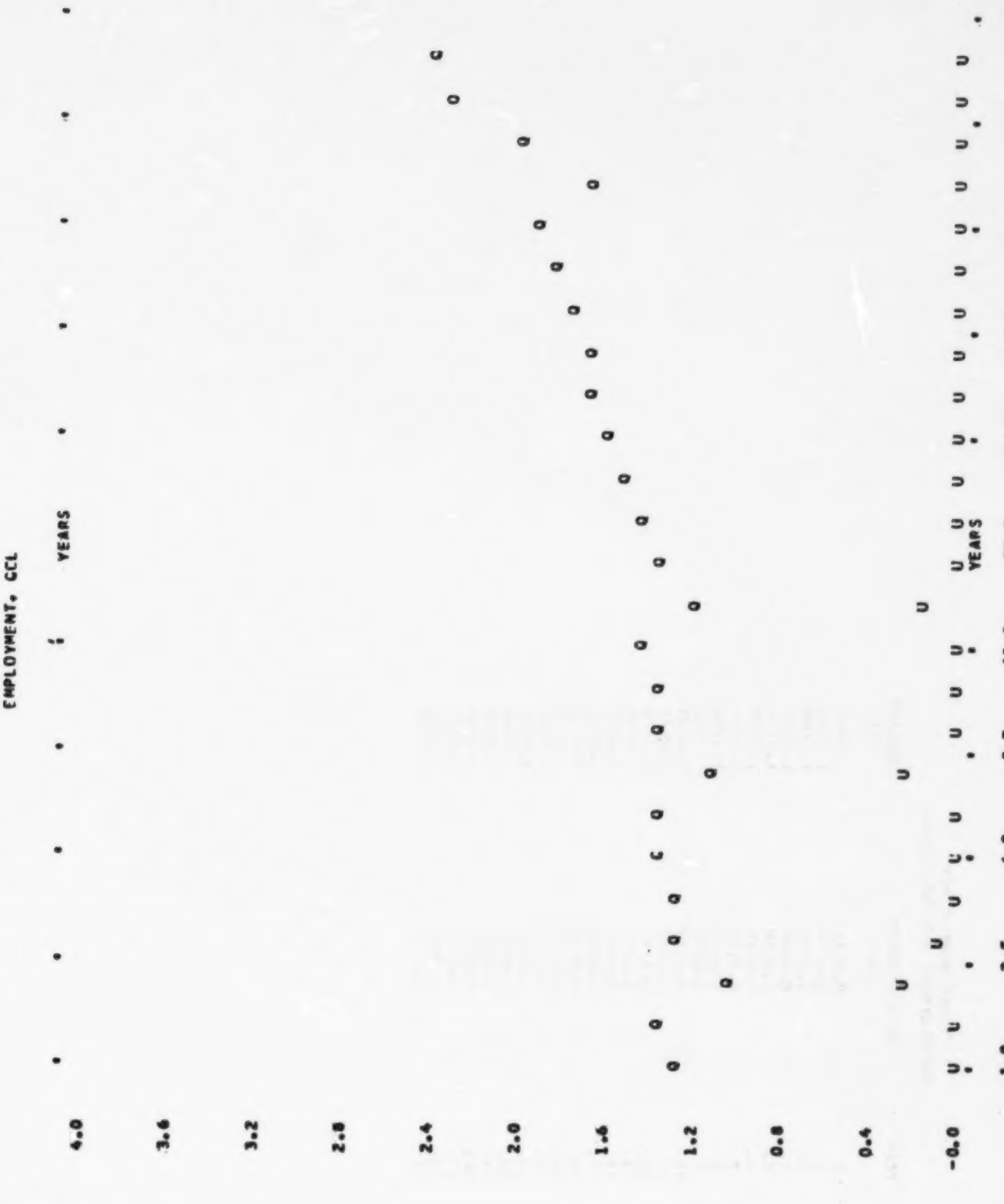
EMPLOYMENT, GCL
YEARS
4.0
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
-0.0
1.0
3.5
6.0
8.5
11.0
13.5
16.0
18.5
21.0
23.5
26.0
YEARS

TABLE NUMBER SEVEN - LAND, AIR AND WATER USAGE
(SCALED TO ORIGINAL VALUE)

YEAR	URBAN (U)	SUBURBAN (S)	ARABLE (F)	TREATED UNITS OF MEDIA (A)	TREATED UNITS OF MEDIA (W)
1.	1.0000	1.0000	1.0000	1.0000	1.0000
2.	1.0335	1.0354	1.0005	1.0453	1.0318
3.	0.9623	0.9512	0.8443	0.8001	0.8576
4.	1.0236	1.0210	0.9202	0.9350	0.9647
5.	1.0546	1.0550	0.9229	0.9818	0.9974
6.	1.0871	1.0905	0.9256	1.0300	1.0313
7.	1.1194	1.1243	0.9263	1.0746	1.0611
8.	1.0690	1.0638	0.7850	0.8717	0.9182
9.	1.1411	1.1421	0.8379	1.0241	1.0193
10.	1.1772	1.1809	0.8407	1.0725	1.0556
11.	1.2135	1.2191	0.8424	1.1190	1.0895
12.	1.0567	1.2654	0.7095	0.9235	0.9512
13.	1.1280	1.3591	0.7740	1.0820	1.0662
14.	1.1668	1.4079	0.7767	1.1319	1.1057
15.	1.2082	1.4600	0.7790	1.1854	1.1475
16.	1.1272	1.6274	0.7814	1.2536	1.2074
17.	1.1672	1.6857	0.7836	1.3078	1.2485
18.	1.2082	1.7479	0.7862	1.3700	1.2965
19.	1.1272	1.9190	0.7886	1.4316	1.3444
20.	1.1670	1.9886	0.7907	1.4942	1.3931
21.	1.1363	1.9492	0.7709	1.5217	1.3870
22.	0.9744	1.6511	0.6989	1.2020	1.1877
23.	0.9569	1.6856	0.7102	1.5402	1.2732
24.	1.0255	1.8048	0.7538	1.6214	1.3740
25.	1.0648	1.8746	0.7861	1.7021	1.4340

LAND(3), AIR AND WATER